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Itoi

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(54) **CONDENSED CYCLIC COMPOUND AND ORGANIC LIGHT-EMITTING DEVICE INCLUDING THE SAME**

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Sep. 20, 2016 (KR) 10-2016-0120139

(51) **Int. Cl.**
H01L 51/00 (2006.01)
C07D 209/90 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC **H01L 51/0056** (2013.01); **C07C 211/54**
(2013.01); **C07C 211/58** (2013.01);
(Continued)

(58) **Field of Classification Search**
None
See application file for complete search history.

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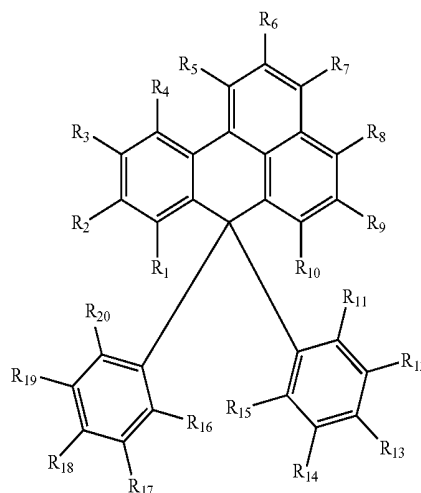
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(57) **ABSTRACT**

A condensed cyclic compound and an organic light-emitting device including the same, the condensed cyclic compound being represented by Formula 1:

<Formula 1>



20 Claims, 1 Drawing Sheet

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190
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110

- (51) **Int. Cl.**
C07D 239/24 (2006.01)
C07D 251/12 (2006.01)
C07D 307/77 (2006.01)
C09K 11/06 (2006.01)
H01L 51/50 (2006.01)
C07D 333/76 (2006.01)
C07C 211/54 (2006.01)
C07C 211/58 (2006.01)
C07C 211/61 (2006.01)
C07D 307/91 (2006.01)
C09B 57/00 (2006.01)
C09B 69/00 (2006.01)
- (52) **U.S. Cl.**
 CPC *C07C 211/61* (2013.01); *C07D 209/90*
 (2013.01); *C07D 239/24* (2013.01); *C07D*
251/12 (2013.01); *C07D 307/77* (2013.01);
C07D 307/91 (2013.01); *C07D 333/76*
 (2013.01); *C09B 57/00* (2013.01); *C09B*
57/008 (2013.01); *C09B 69/008* (2013.01);
C09K 11/06 (2013.01); *H01L 51/006*
 (2013.01); *H01L 51/0054* (2013.01); *H01L*
51/0058 (2013.01); *H01L 51/0059* (2013.01);
H01L 51/504 (2013.01); *H01L 51/5056*
 (2013.01); *H01L 51/5072* (2013.01); *C07C*
2603/18 (2017.05); *C07C 2603/42* (2017.05);
C07C 2603/97 (2017.05)

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FIG. 1

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FIG. 2

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FIG. 3

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FIG. 4

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CONDENSED CYCLIC COMPOUND AND
ORGANIC LIGHT-EMITTING DEVICE
INCLUDING THE SAME

CROSS-REFERENCE TO RELATED
APPLICATION

Korean Patent Application No. 10-2016-0120139, filed on Sep. 20, 2016, in the Korean Intellectual Property Office, and entitled: "Condensed Cyclic Compound and Organic Light-Emitting Device Including the Same," is incorporated by reference herein in its entirety.

BACKGROUND

1. Field

Embodiments relate to a compound for an organic light-emitting device and an organic light-emitting device including the same.

2. Description of the Related Art

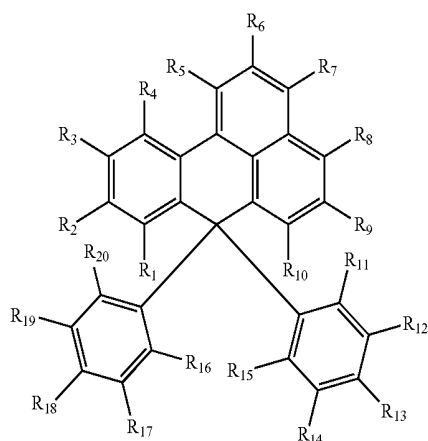
Organic light-emitting devices are self-emission devices that produce full-color images, having wide viewing angles, high contrast ratios, and short response times, as well as excellent brightness, driving voltage, and response speed characteristics as compared with devices in the art.

An example of such organic light-emitting devices may include a first electrode disposed on a substrate, and a hole transport region, an emission layer, an electron transport region, and a second electrode, which are sequentially disposed on the first electrode. Holes provided from the first electrode may move toward the emission layer through the hole transport region, and electrons provided from the second electrode may move toward the emission layer through the electron transport region. Carriers, such as holes and electrons, recombine in the emission layer to produce excitons. These excitons transition from an excited state to a ground state, thereby generating light.

SUMMARY

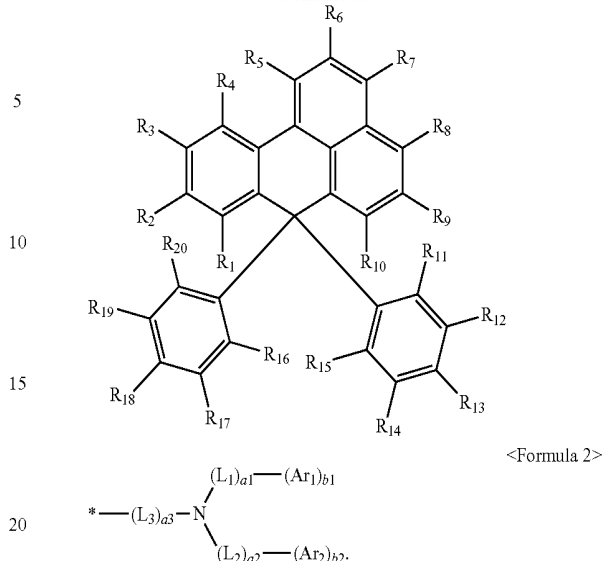
Embodiments are directed to a compound for an organic light-emitting device and an organic light-emitting device including the same.

The embodiments may be realized by providing a condensed cyclic compound represented by Formula 1:



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-continued



In Formulae 1 and 2,

L1 to L3 are each independently a substituted or unsubstituted C3-C60 carbocyclic group or a substituted or unsubstituted C1-C60 heterocyclic group,

a1 is an integer from 0 to 3, wherein when a1 is two or more, two or more L1(s) are identical to or different from each other, a2 is an integer from 0 to 3, wherein when a2 is two or more, two or more L2(s) are identical to or different from each other, and a3 is an integer from 0 to 3, wherein when a3 is two or more, two or more L3(s) are identical to or different from each other,

Ar1 and Ar2 are each independently selected from a substituted or unsubstituted C3-C10 cycloalkyl group, a substituted or unsubstituted C1-C10 heterocycloalkyl group, a substituted or unsubstituted C3-C10 cycloalkenyl group, a substituted or unsubstituted C1-C10 heterocycloalkenyl group, a substituted or unsubstituted C6-C60 aryl group, a substituted or unsubstituted C6-C60 aryloxy group, a substituted or unsubstituted C6-C60 arylthio group, a substituted or unsubstituted C1-C60 heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group,

b1 is an integer from 0 to 3, wherein when b1 is two or more, two or more Ar1(s) are identical to or different from each other, and b2 is an integer from 0 to 3, wherein when b2 is two or more, two or more Ar2(s) are identical to or different from each other,

R1 to R20 are each independently selected from a group represented by Formula 2, hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a substituted or unsubstituted C1-C60 alkyl group, a substituted or unsubstituted C2-C60 alkenyl group, a substituted or unsubstituted C2-C60 alkynyl group, a substituted or unsubstituted C1-C60 alkoxy group, a substituted or unsubstituted C3-C10 cycloalkyl group, a substituted or unsubstituted C1-C10 heterocycloalkyl group, a substituted or unsubstituted C3-C10 cycloalkenyl group, a substituted or unsubstituted C1-C10 heterocycloalkenyl group, a substituted or unsubstituted C6-C60 aryl group, a substituted or unsubstituted C6-C60 aryloxy group, a substituted or unsubstituted C6-C60 arylthio group, a substituted or unsubstituted C1-C60 heteroaryl group, a substituted or unsubstituted

tuted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, $-\text{Si}(\text{Q1})(\text{Q2})(\text{Q3})$, $-\text{B}(\text{Q1})(\text{Q2})$, $-\text{C}(=\text{O})(\text{Q1})$, $-\text{S}(=\text{O})_2(\text{Q1})$, and $-\text{P}(=\text{O})(\text{Q1})(\text{Q2})$, provided that R1 to R10 are not a group represented by Formula 2,

at least one selected from R11 to R20 may be a group represented by Formula 2,

at least one substituent of the substituted C3-C60 carbocyclic group, the substituted C1-C60 heterocyclic group, the substituted C1-C60 alkyl group, the substituted C2-C60 alkenyl group, the substituted C2-C60 alkynyl group, the substituted C1-C60 alkoxy group, the substituted C3-C10 cycloalkyl group, the substituted C1-C10 heterocycloalkyl group, the substituted C3-C10 cycloalkenyl group, the substituted C1-C10 heterocycloalkenyl group, the substituted C6-C60 aryl group, the substituted C6-C60 aryloxy group, the substituted C6-C60 arylthio group, the substituted C1-C60 heteroaryl group, the substituted monovalent non-aromatic condensed polycyclic group, and the substituted monovalent non-aromatic condensed heteropolycyclic group is selected from: deuterium, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazino group, a hydrazono group, a C1-C60 alkyl group, a C2-C60 alkenyl group, a C2-C60 alkynyl group, and a C1-C60 alkoxy group; a C1-C60 alkyl group, a C2-C60 alkenyl group, a C2-C60 alkynyl group, and a C1-C60 alkoxy group, each substituted with at least one selected from deuterium, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazino group, a hydrazono group, a C3-C10 cycloalkyl group, a C1-C10 heterocycloalkyl group, a C3-C10 cycloalkenyl group, a C1-C10 heterocycloalkenyl group, a C6-C60 aryl group, a C6-C60 aryloxy group, a C6-C60 arylthio group, a C1-C60 heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, $-\text{Si}(\text{Q11})(\text{Q12})(\text{Q13})$, $-\text{B}(\text{Q11})(\text{Q12})$, $-\text{C}(=\text{O})(\text{Q11})$, $-\text{S}(=\text{O})_2(\text{Q11})$, and $-\text{P}(=\text{O})(\text{Q11})(\text{Q12})$; a C3-C10 cycloalkyl group, a C1-C10 heterocycloalkyl group, a C3-C10 cycloalkenyl group, a C1-C10 heterocycloalkenyl group, a C6-C60 aryl group, a C6-C60 aryloxy group, a C6-C60 arylthio group, a C1-C60 heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group; a C3-C10 cycloalkyl group, a C1-C10 heterocycloalkyl group, a C3-C10 cycloalkenyl group, a C1-C10 heterocycloalkenyl group, a C6-C60 aryl group, a C6-C60 aryloxy group, a C6-C60 arylthio group, a C1-C60 heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group, each substituted with at least one selected from deuterium, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazino group, a hydrazono group, a C1-C60 alkyl group, a C2-C60 alkenyl group, a C2-C60 alkynyl group, a C1-C60 alkoxy group, a C3-C10 cycloalkyl group, a C1-C10 heterocycloalkyl group, a C3-C10 cycloalkenyl group, a C1-C10 heterocycloalkenyl group, a C6-C60 aryl group, a C6-C60 aryloxy group, a C6-C60 arylthio group, a C1-C60 heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group, and

C6-C60 aryloxy group, a C6-C60 arylthio group, a C1-C60 heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, a terphenyl group, $-\text{Si}(\text{Q21})(\text{Q22})(\text{Q23})$, $-\text{B}(\text{Q21})(\text{Q22})$, $-\text{C}(=\text{O})(\text{Q21})$, $-\text{S}(=\text{O})_2(\text{Q21})$, and $-\text{P}(=\text{O})(\text{Q21})(\text{Q22})$; and $-\text{Si}(\text{Q31})(\text{Q32})(\text{Q33})$, $-\text{B}(\text{Q31})(\text{Q32})$, $-\text{C}(=\text{O})(\text{Q31})$, $-\text{S}(=\text{O})_2(\text{Q31})$, and $-\text{P}(=\text{O})(\text{Q31})(\text{Q32})$, Q1 to Q3, Q11 to Q13, Q21 to Q23, and Q31 to Q33 are each independently selected from hydrogen, deuterium, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazino group, a hydrazono group, a C1-C60 alkyl group, a C2-C60 alkenyl group, a C2-C60 alkynyl group, a C1-C60 alkoxy group, a C3-C10 cycloalkyl group, a C1-C10 heterocycloalkyl group, a C3-C10 cycloalkenyl group, a C1-C10 heterocycloalkenyl group, a C6-C60 aryl group, a C1-C60 heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group, and * indicates a binding site to a neighboring atom.

The embodiments may be realized by providing an organic light-emitting device including a first electrode; a second electrode facing the first electrode; and an organic layer between the first electrode and the second electrode, the organic layer including an emission layer, wherein the organic layer includes the condensed cyclic compound according to an embodiment.

BRIEF DESCRIPTION OF THE DRAWINGS

Features will be apparent to those of skill in the art by describing in detail exemplary embodiments with reference to the attached drawings in which:

FIG. 1 illustrates a schematic cross-sectional view of an organic light-emitting device according to an embodiment;

FIG. 2 illustrates a schematic cross-sectional view of an organic light-emitting device according to an embodiment;

FIG. 3 illustrates a schematic view of an organic light-emitting device according to an embodiment; and

FIG. 4 illustrates a schematic view of an organic light-emitting device according to an embodiment.

DETAILED DESCRIPTION

Example embodiments will now be described more fully hereinafter with reference to the accompanying drawings; however, they may be embodied in different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey exemplary implementations to those skilled in the art.

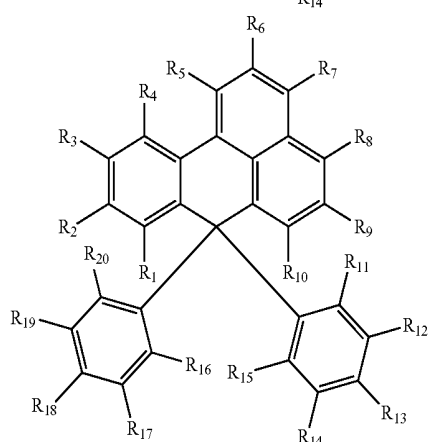
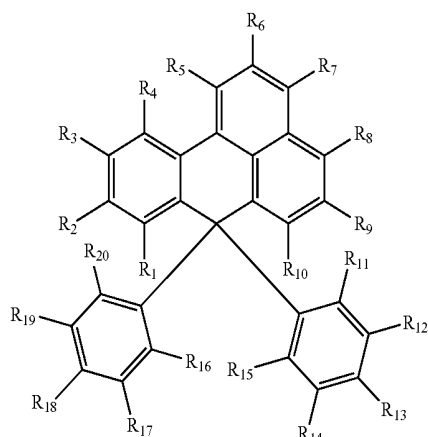
In the drawing figures, the dimensions of layers and regions may be exaggerated for clarity of illustration. It will also be understood that when a layer or element is referred to as being "on" another layer or element, it can be directly on the other layer or element, or intervening layers may also be present. In addition, it will also be understood that when a layer is referred to as being "between" two layers, it can be the only layer between the two layers, or one or more intervening layers may also be present. Like reference numerals refer to like elements throughout.

According to one or more embodiments, a condensed cyclic compound may be represented by Formula 1:

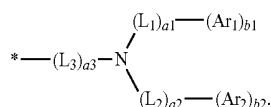
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<Formula 1>



<Formula 2>



wherein, in Formulae 1 and 2,

L_1 to L_3 may each independently be or include, e.g., a substituted or unsubstituted C_3 - C_{60} carbocyclic group or a substituted or unsubstituted C_1 - C_{60} heterocyclic group.

In one or more embodiments, L_1 to L_3 may each independently be selected from:

a benzene group, a pentalene group, an indene group, a naphthalene group, an azulene group, a heptalene group, an indacene group, an acenaphthalene group, a fluorene group, a spiro-bifluorene group, a spiro-benzofluorene-fluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pyrrole group, a thiophene group, a furan group, a silole group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, a triazine group, a benzofuran group, a benzothiophene group, a benzosilole group, a dibenzofuran group, a dibenzothiophene group, a dibenzosilole group, a carbazole group, a benzocarbazole group, a dibenzocarbazole group, a benzimidazole group, and an imidazopyridine group; and

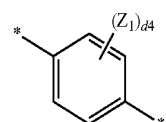
a benzene group, a pentalene group, an indene group, a naphthalene group, an azulene group, a heptalene group, an indacene group, an acenaphthalene group, a fluorene group,

a spiro-bifluorene group, a spiro-benzofluorene-fluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pyrrole group, a thiophene group, a furan group, a silole group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, a triazine group, a benzofuran group, a benzothiophene group, a benzosilole group, a dibenzofuran group, a dibenzothiophene group, a dibenzosilole group, a carbazole group, a benzocarbazole group, a dibenzocarbazole group, a benzimidazole group, and an imidazopyridine group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, a carbazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, —Si(Q_{31})(Q_{32})(Q_{33}), and —B(Q_{31})(Q_{32}),

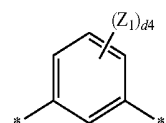
Q_{31} to Q_{33} may each independently be selected from a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, and a pyridinyl group, and

* indicates a binding site to a neighboring atom.

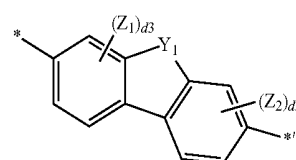
In one or more embodiments, L_1 to L_3 may each independently be selected from groups represented by Formulae 3-1 to 3-49:



Formula 3-1



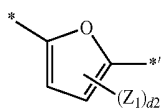
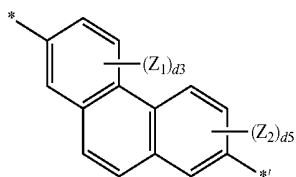
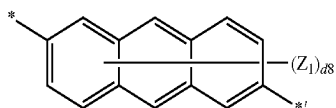
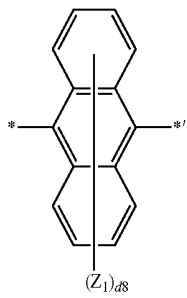
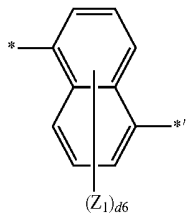
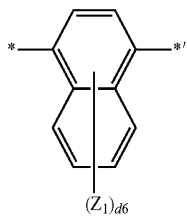
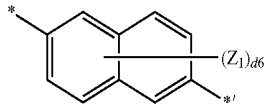
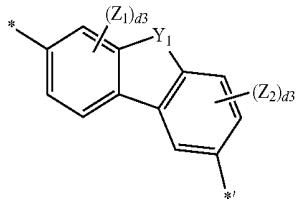
Formula 3-2



Formula 3-3

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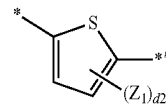


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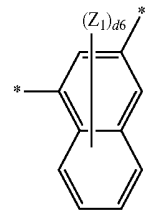
Formula 3-4

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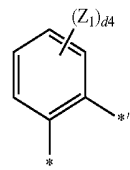
Formula 3-5

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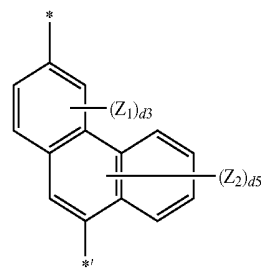
Formula 3-6

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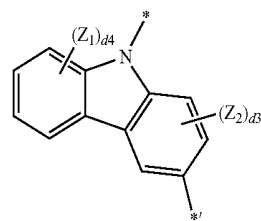
Formula 3-7

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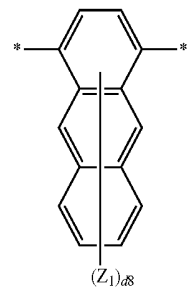
Formula 3-8

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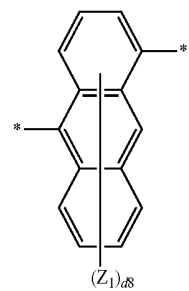
Formula 3-9

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Formula 3-10

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Formula 3-11

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Formula 3-12

Formula 3-13

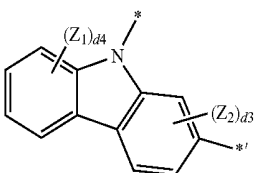
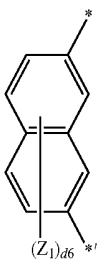
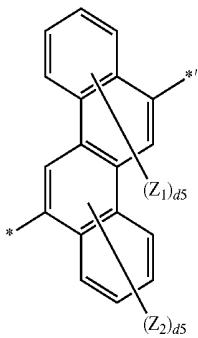
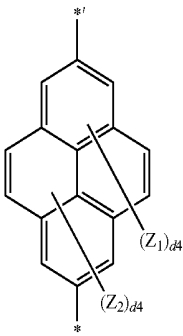
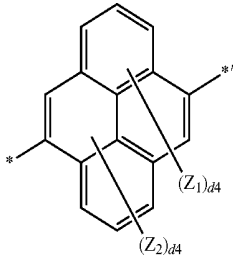
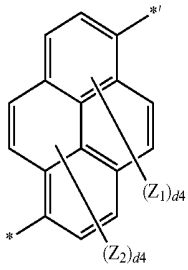
Formula 3-14

Formula 3-15

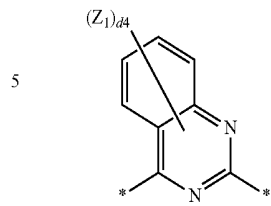
Formula 3-16

Formula 3-17

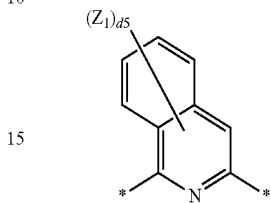
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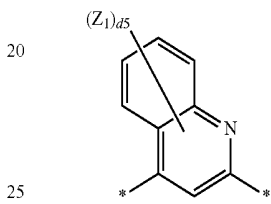
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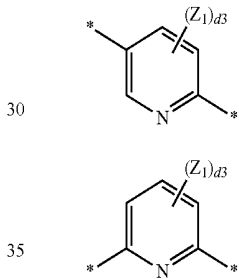
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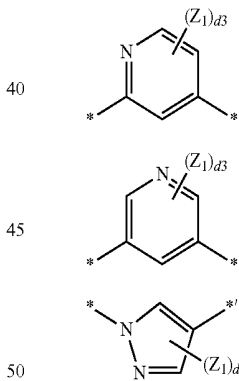
Formula 3-21



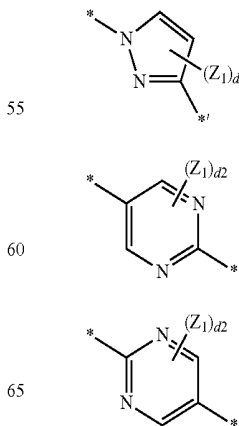
Formula 3-22



Formula 3-23



Formula 3-24



Formula 3-25

Formula 3-26

Formula 3-27

Formula 3-28

Formula 3-29

Formula 3-30

Formula 3-31

Formula 3-32

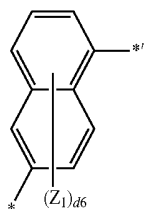
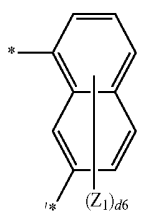
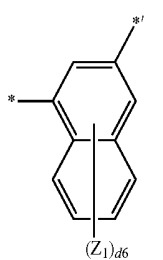
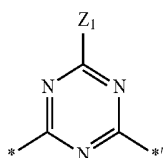
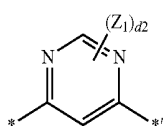
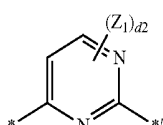
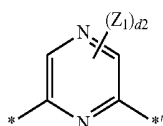
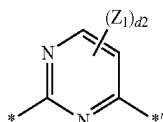
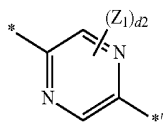
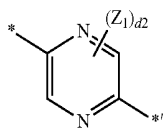
Formula 3-33

Formula 3-34

Formula 3-35

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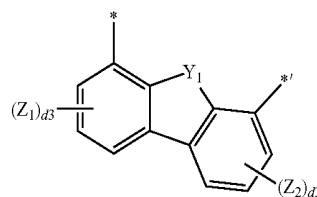


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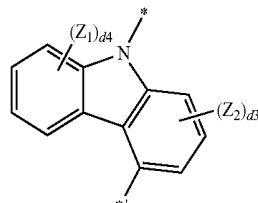
Formula 3-36

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Formula 3-37

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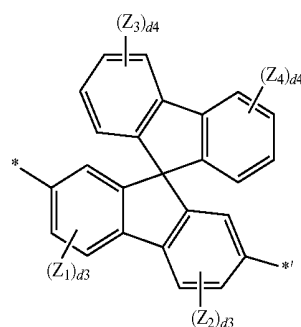


Formula 3-38

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Formula 3-39

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Formula 3-40

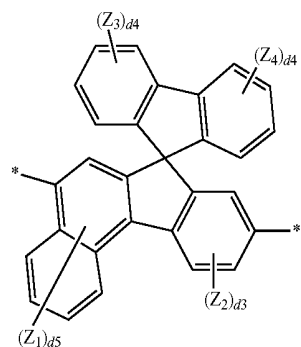
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Formula 3-41

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Formula 3-42

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Formula 3-43

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In Formulae 3-1 to 3-49,

Y₁ may be O, S, C(Z₅)(Z₆), N(Z₅), or Si(Z₅)(Z₆).

Z₁ to Z₆ may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkenyl group, a C₁-C₂₀ alkynyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a triazinyl group, —Si(Q₃₁)(Q₃₂)(Q₃₃), —B(Q₃₁)(Q₃₂), —C(=O)(Q₃₁), —S(=O)₂(Q₃₁), and —P(=O)(Q₃₁)(Q₃₂),

Formula 3-45

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wherein Q₃₁ to Q₃₃ may each independently be selected from a C₁-C₁₀ alkyl group, a C₁-C₁₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group,

65

d₂ may be 1 or 2,d₃ may be an integer of 1 to 3,

Formula 3-46

Formula 3-47

Formula 3-48

Formula 3-49

13

d4 may be an integer of 1 to 4,

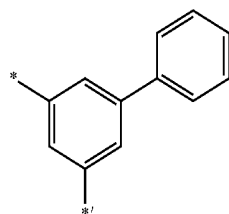
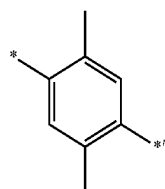
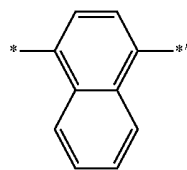
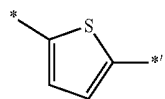
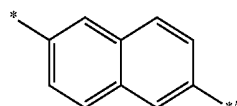
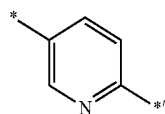
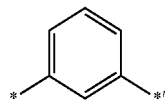
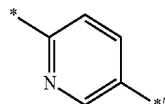
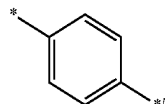
d5 may be an integer of 1 to 5,

d6 may be an integer of 1 to 6,

d8 may be an integer of 1 to 8, and

* and *' each indicate a binding site to a neighboring atom.

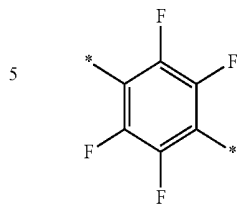
In an implementation, L₁ to L₃ may each independently be, e.g., a group represented by one of Formulae 4-1 to 4-39.



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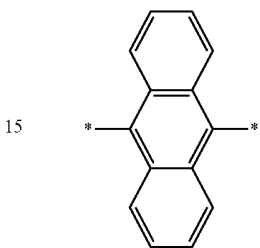
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Formula 4-10

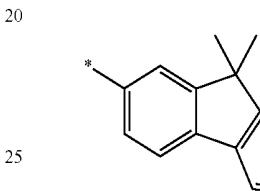


Formula 4-11

Formula 4-1

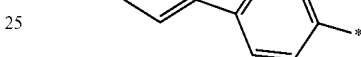


Formula 4-2

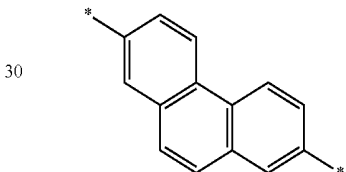


Formula 4-12

Formula 4-3

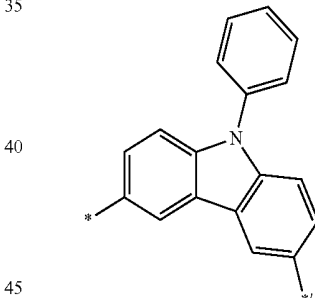


Formula 4-4



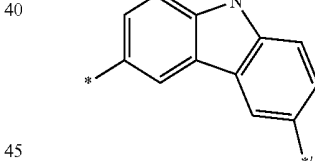
Formula 4-13

Formula 4-5

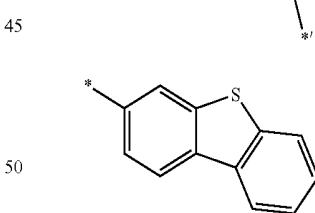


Formula 4-14

Formula 4-6

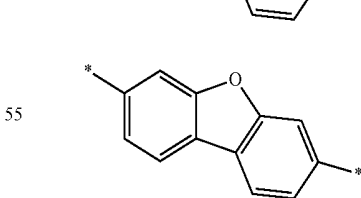


Formula 4-7



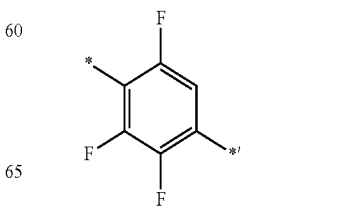
Formula 4-15

Formula 4-8



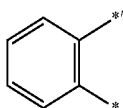
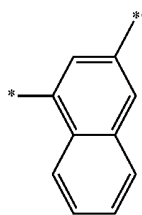
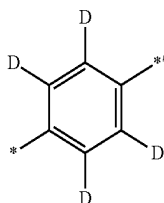
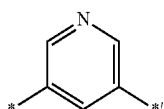
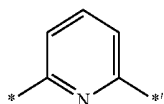
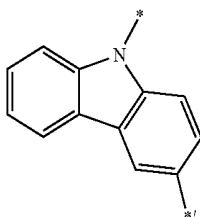
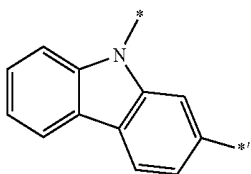
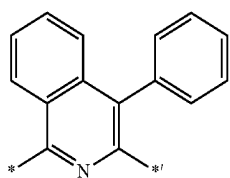
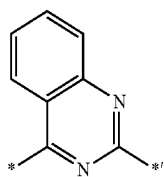
Formula 4-16

Formula 4-9



Formula 4-17

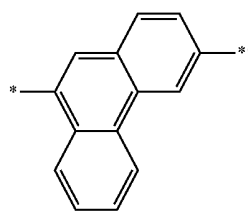
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Formula 4-18

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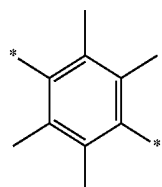


Formula 4-19

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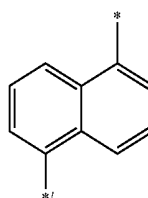
Formula 4-20

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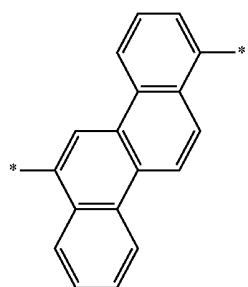
Formula 4-21

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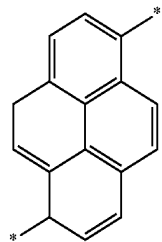
Formula 4-22

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Formula 4-23

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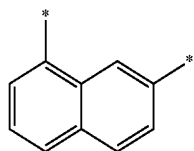


Formula 4-24

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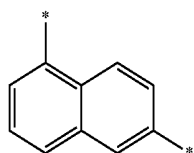
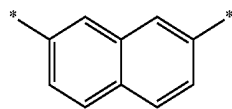
Formula 4-25

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Formula 4-26

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Formula 4-27

Formula 4-28

Formula 4-29

Formula 4-30

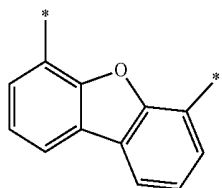
Formula 4-31

Formula 4-32

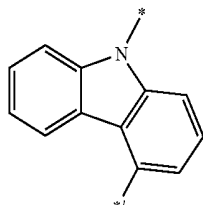
Formula 4-33

Formula 4-34

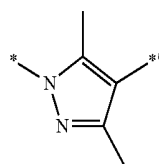
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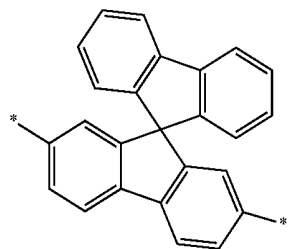
Formula 4-35



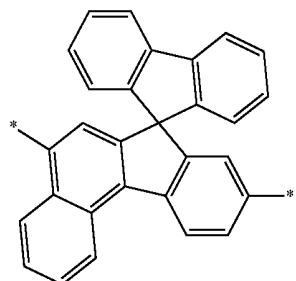
Formula 4-36



Formula 4-37



Formula 4-38



Formula 4-39

* and *' each indicate a binding site to a neighboring atom.

In one or more embodiments, L_1 to L_3 may each independently be selected from:

a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, a spiro-benzofluorene-fluorene group, a benzofluorene group, a dibenzofluorene group, a phenanthrene group, an anthracene group, a dibenzofuran group, a dibenzothiophene group, a dibenzosilole group, and a carbazole group; and

a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, a spiro-benzofluorene-fluorene group, a benzofluorene group, a dibenzofluorene group, a phenanthrene group, an anthracene group, a dibenzofuran group, a dibenzothiophene group, a dibenzosilole group, and a carbazole group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, —Si(Q_{31})(Q_{32})(Q_{33}), and —B(Q_{31})(Q_{32}),

wherein Q_{31} to Q_{33} may each independently be selected from a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl

group, a biphenyl group, a terphenyl group, a naphthyl group, and a pyridinyl group.

For example, L_1 to L_3 may each independently be selected from:

5 a benzene group; and

a benzene group, substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

In Formula 2,

a1 may be an integer of 0 to 3, wherein when a1 is two or more, the two or more L_1 (s) may be identical to or different from each other, a2 may be an integer of 0 to 3, wherein when a2 is two or more, the two or more L_2 (s) may be identical to or different from each other, a3 may be an integer of 0 to 3, wherein when a3 is two or more, the two or more L_3 (s) may be identical to or different from each other.

20 In one or more embodiments, a1 to a3 may each independently be 0 or 1.

In an implementation, in Formula 2, Ar_1 and Ar_2 may each independently be selected from or include, e.g., a substituted or unsubstituted C_3 - C_{10} cycloalkyl group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3 - C_{10} cycloalkenyl group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6 - C_{60} aryl group, a substituted or unsubstituted C_6 - C_{60} aryloxy group, a substituted or unsubstituted C_6 - C_{60} arylthio group, a substituted or unsubstituted C_1 - C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group.

35 In one or more embodiments, Ar_1 and Ar_2 may each independently be selected from:

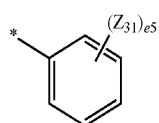
a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacacenyl group, a pentacacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a thiophenyl group, a furanyl group, a carbazolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzonaphthofuranyl group, a dinaphthofuranyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a benzonaphthosilolyl group, a dinaphthosilolyl group, a benzimidazolyl group, a benzoimidazonaphthoimidazolyl group, and an imidazopyridinyl group; and

a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacacenyl group, a pentacacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyridinyl group, a

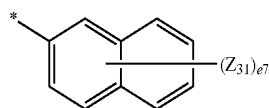
pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a thiophenyl group, a furanyl group, a carbazolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzonaphthofuranyl group, a dinaphthofuranyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a benzonaphthosilolyl group, a dinaphthosilolyl group, a benzimidazolyl group, a benzoimidazonaphthoimidazolyl group, and an imidazopyridinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacacenyl group, a pentacacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a thiophenyl group, a furanyl group, a carbazolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, and —Si(Q₃₁)(Q₃₂)(Q₃₃).

wherein Q₃ to Q₃₃ may each independently be selected from a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

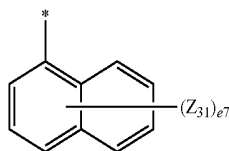
In an implementation, Ar₁ and Ar₂ may each independently be a group represented by one of the following Formulae 5-1 to 5-30.



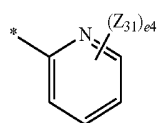
Formula 5-1



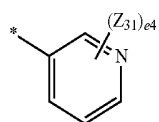
Formula 5-2



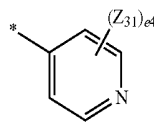
Formula 5-3



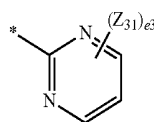
Formula 5-4



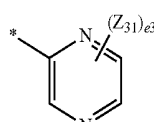
Formula 5-5



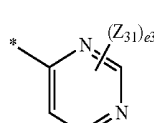
Formula 5-6



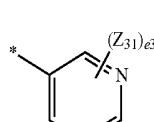
Formula 5-7



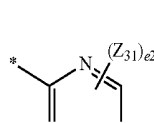
Formula 5-8



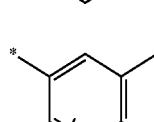
Formula 5-9



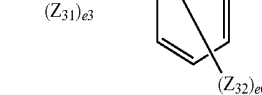
Formula 5-10



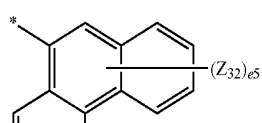
Formula 5-11



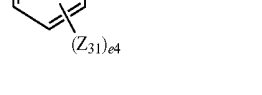
Formula 5-12



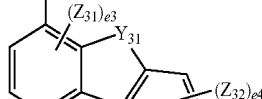
Formula 5-13



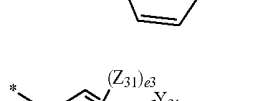
Formula 5-14



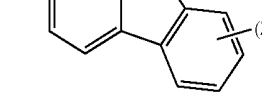
Formula 5-15



Formula 5-16



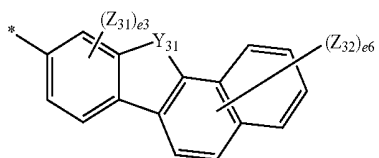
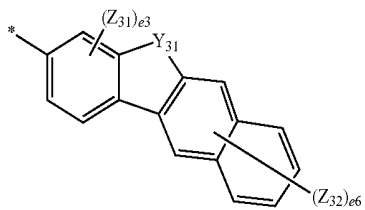
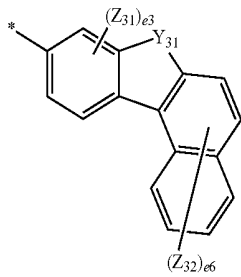
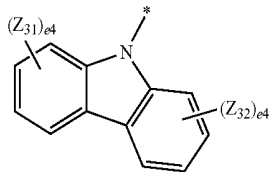
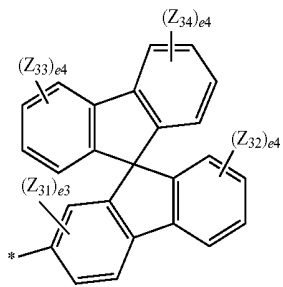
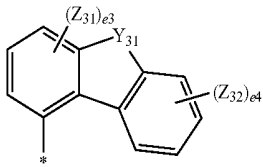
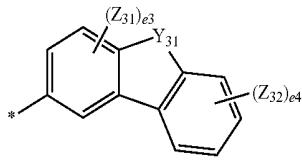
Formula 5-17



Formula 5-18

-continued

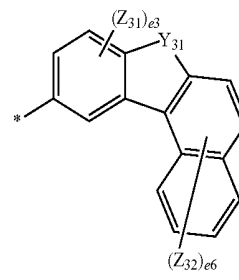
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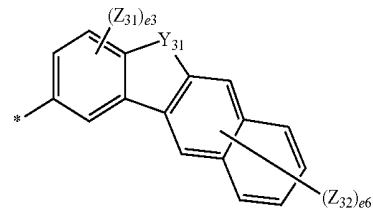
Formula 5-16

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Formula 5-17 10

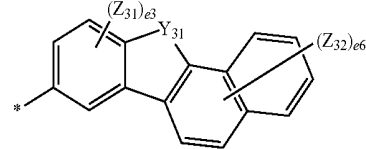
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Formula 5-18

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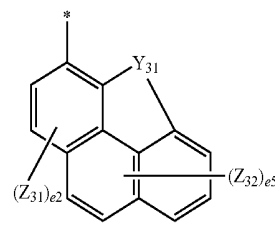
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Formula 5-19

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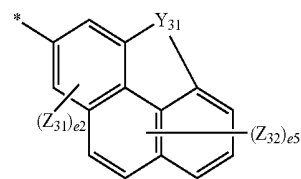
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Formula 5-20

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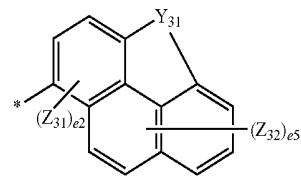
45



Formula 5-21

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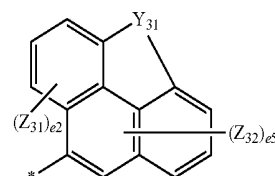
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Formula 5-22

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Formula 5-23

Formula 5-24

Formula 5-25

Formula 5-26

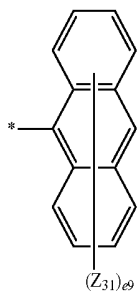
Formula 5-27

Formula 5-28

Formula 5-29

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In Formulae 5-1 to 5-30,

Y₃₁ may be O, S, C(Z₃₅)(Z₃₆), N(Z₃₅), or Si(Z₃₅)(Z₃₆),

Z₃₁ to Z₃₆ may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkenyl group, a C₁-C₂₀ alkynyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a triazinyl group, —Si(Q₃₁)(Q₃₂)(Q₃₃), —B(Q₃₁)(Q₃₂), —C(=O)(Q₃₁), —S(=O)₂(Q₃₁), and —P(=O)(Q₃₁)(Q₃₂),

wherein Q₃₁ to Q₃₃ may each independently be selected from a C₁-C₁₀ alkyl group, a C₁-C₁₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group,

e₂ may be 1 or 2,

e₃ may be an integer of 1 to 3,

e₄ may be an integer of 1 to 4,

e₅ may be an integer of 1 to 5,

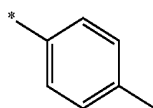
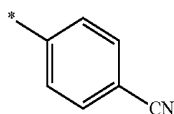
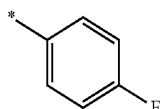
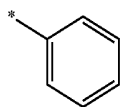
e₆ may be an integer of 1 to 6,

e₇ may be an integer of 1 to 7,

e₉ may be an integer of 1 to 9, and

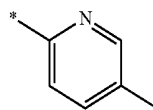
* and *' each indicate a binding site to a neighboring atom.

In an implementation, Ar₁ and Ar₂ may each independently be a group represented by one of the following Formulae 6-1 to 6-58.

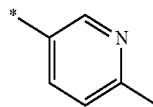


Formula 5-30

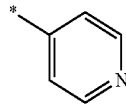
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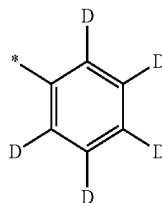
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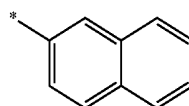


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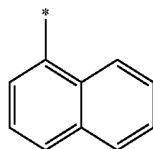


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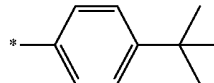
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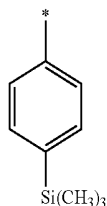
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Formula 6-1

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Formula 6-2

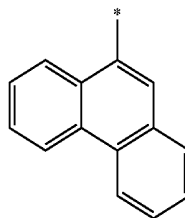
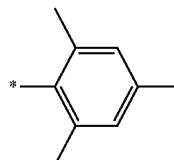
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Formula 6-3

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Formula 6-4

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Formula 6-5

Formula 6-6

Formula 6-7

Formula 6-8

Formula 6-9

Formula 6-10

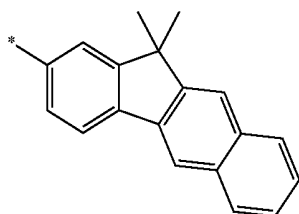
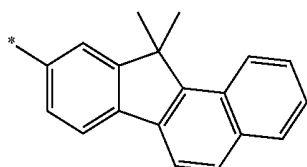
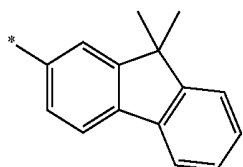
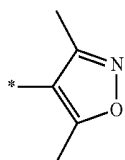
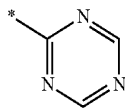
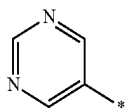
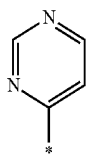
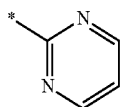
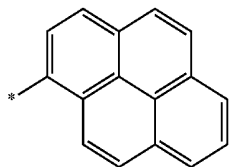
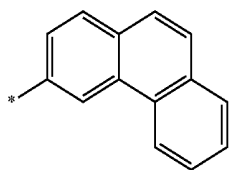
Formula 6-11

Formula 6-12

Formula 6-13

Formula 6-14

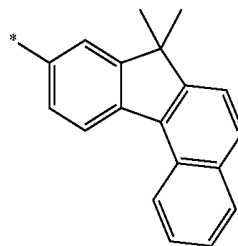
25
-continued



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Formula 6-15

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Formula 6-16

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Formula 6-17

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Formula 6-18

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Formula 6-19

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Formula 6-20

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Formula 6-22

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Formula 6-23

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Formula 6-24

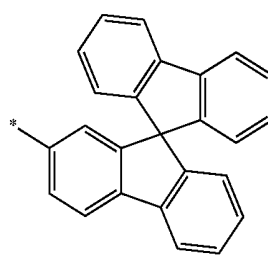
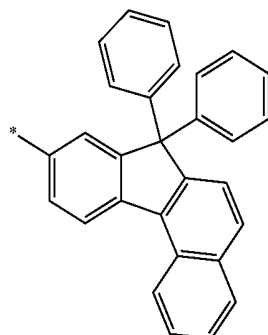
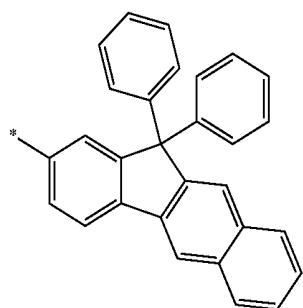
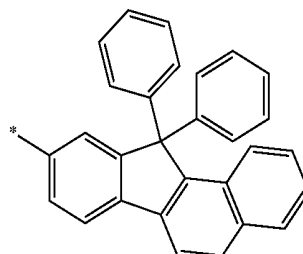
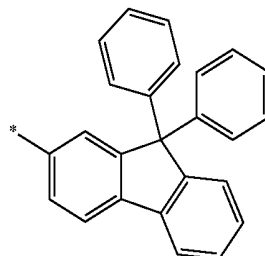
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Formula 6-25

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Formula 6-26

Formula 6-27

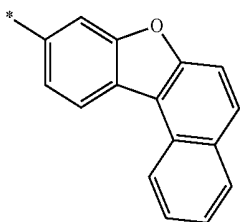
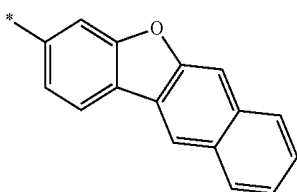
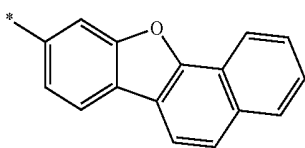
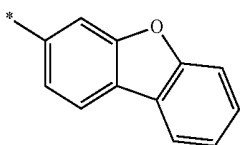
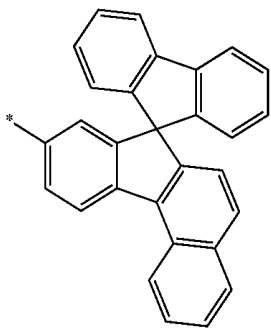
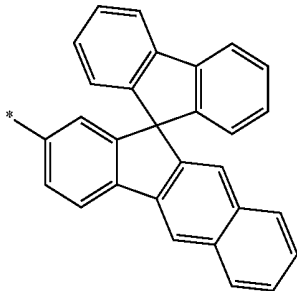
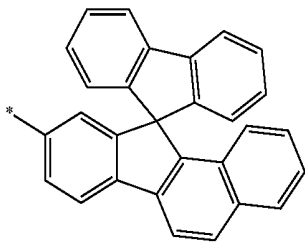
Formula 6-28

Formula 6-29

Formula 6-30

Formula 6-31

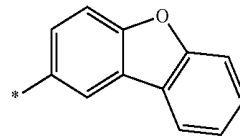
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-continued

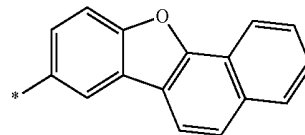
Formula 6-32

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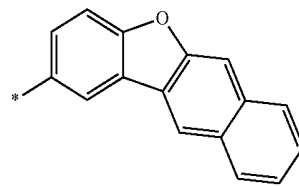


Formula 6-33

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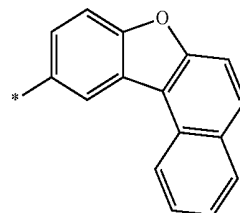
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Formula 6-34

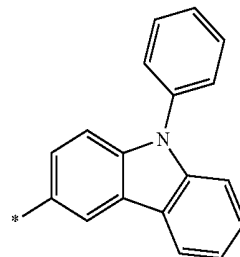
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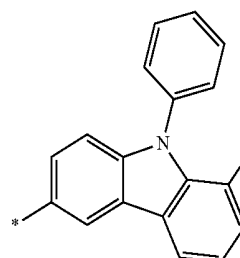
Formula 6-35

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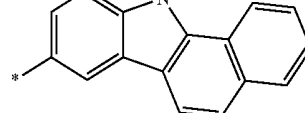
Formula 6-36

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Formula 6-37

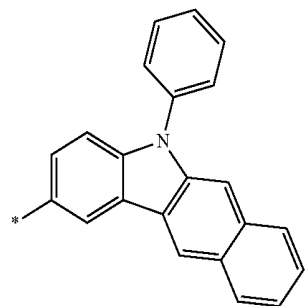
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Formula 6-38

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Formula 6-39

Formula 6-40

Formula 6-41

Formula 6-42

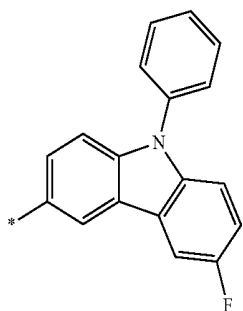
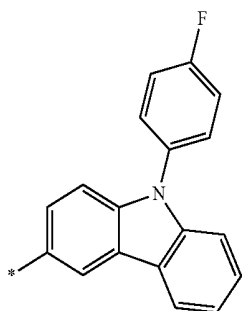
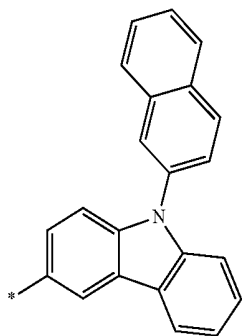
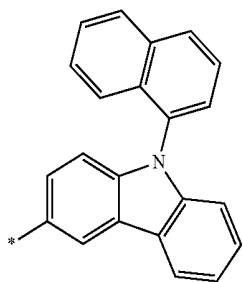
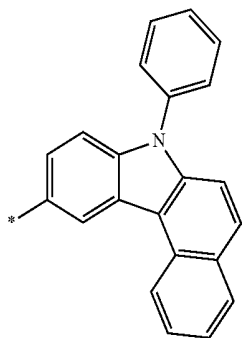
Formula 6-43

Formula 6-44

Formula 6-45

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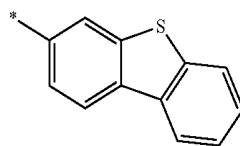


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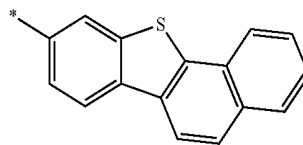
Formula 6-46

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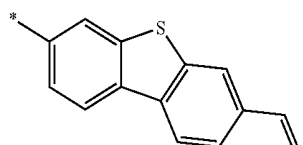


Formula 6-47

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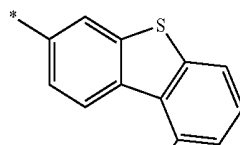
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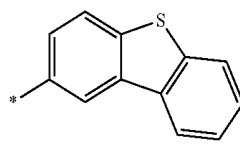
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Formula 6-48

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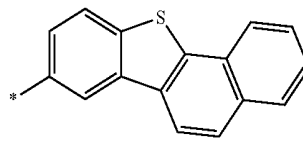
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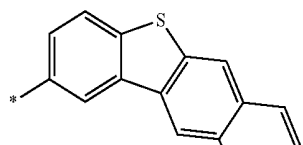
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Formula 6-49

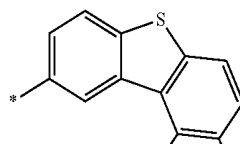
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Formula 6-50

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Formula 6-51

Formula 6-52

Formula 6-53

Formula 6-54

Formula 6-55

Formula 6-56

Formula 6-57

Formula 6-58

* indicates a binding site to a neighboring atom.

60 In an implementation, Ar₁ and Ar₂ may each independently be selected from, e.g.,

a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a carbazolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzonaphtho furanyl group, a dinaphtho furanyl group, a

benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a benzonaphthosilolyl group, and a dinaphthosilolyl group; and

a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a carbazolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzonaphthofuranyl group, a dinaphthofuranyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a benzonaphthosilolyl group, and a dinaphthosilolyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, and —Si(Q₃₁)(Q₃₂)(Q₃₃),

wherein Q₃₁ to Q₃₃ may each independently be selected from a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

In an implementation, Ar₁ and Ar₂ may each independently be selected from, e.g.,

a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a dibenzofuranyl group, and a dibenzothiophenyl group; and

a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, and —Si(Q₃₁)(Q₃₂)(Q₃₃),

wherein Q₃₁ to Q₃₃ may each independently be selected from a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

In Formula 2, b1 may be an integer of 0 to 3, wherein when b1 is two or more, the two or more Ar₁(s) may be identical to or different from each other, b2 may be an integer of 0 to 3, wherein when b2 is two or more, the two or more Ar₂(s) may be identical to or different from each other.

In an implementation, b1 and b2 may each be 1. In an implementation, if all of a1 to a3, b1, and b2 are 0, the group represented by Formula 2 may be an unsubstituted amine group (—NH₂).

In an implementation, in Formula 1, R₁ to R₂₀ may each independently be selected from a group represented by Formula 2, hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a substituted or unsubstituted C₁-C₆₀ alkyl group, a substituted or unsubstituted C₂-C₆₀ alkenyl group, a substituted or unsubstituted C₂-C₆₀ alkenyl group, a substituted or unsubstituted C₁-C₆₀ alkoxy group, a substituted or unsubstituted C₃-C₁₀ cycloalkyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkyl group, a substituted or unsubstituted C₃-C₁₀ cycloalkenyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkenyl group, a substituted or unsubstituted C₆-C₆₀ aryl group, a substituted or unsubstituted C₆-C₆₀ aryloxy group, a substituted or unsubstituted C₆-C₆₀ arylthio group, a substituted or unsubstituted C₁-C₆₀ heteroaryl group, a substituted or unsubstituted monovalent

non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —Si(Q₁)(Q₂)(Q₃), —B(Q₁)(Q₂), —C(=O)(Q₁), —S(=O)₂(Q₁), and —P(=O)(Q₁)(Q₂), provided that R₁ to R₁₀ are not a group represented by Formula 2, and at least one selected from R₁₁ to R₂₀ is a group represented by Formula 2.

In an implementation, R₁ to R₂₀ may each independently be selected from, e.g.,

a group represented by Formula 2;

hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a C₁-C₂₀ alkyl group, and a C₁-C₂₀ alkoxy group;

a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a thiophenyl group, a furanyl group, a carbazolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzonaphthofuranyl group, a dinaphthofuranyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a benzonaphthosilolyl group, a dinaphthosilolyl group, a benzimidazolyl group, a benzoimidazonaphthoimidazolyl group, and an imidazopyridinyl group;

a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a thiophenyl group, a furanyl group, a carbazolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzonaphthofuranyl group, a dinaphthofuranyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a benzonaphthosilolyl group, a dinaphthosilolyl group, a benzimidazolyl group, a benzoimidazonaphthoimidazolyl group, and an imidazopyridinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, and —Si(Q₃₁)(Q₃₂)(Q₃₃);

—Si(Q₁)(Q₂)(Q₃), B(Q₁)(Q₂), —C(=O)(Q₁), —S(=O)₂(Q₁), and —P(=O)(Q₁)(Q₂),

wherein Q₁ to Q₃ and Q₃₁ to Q₃₃ may each independently be selected from a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

In an implementation, R_1 to R_{20} may each independently be selected from, e.g.,

a group represented by Formula 2;

hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a C_1 - C_{20} alkyl group, and a C_1 - C_{20} alkoxy group;

a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group;

a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, and —Si(Q_{31})(Q_{32})(Q_{33}); and

—Si(Q_1)(Q_2)(Q_3), B(Q_1)(Q_2), —C(=O)(Q_1), —S(=O)₂(Q_1), and —P(=O)(Q_1)(Q_2),

wherein Q_1 to Q_3 and Q_{31} to Q_{33} may each independently be selected from a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

In an implementation, in Formulae 1 and 2,

L_1 to L_3 may each independently be selected from:

a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, a spiro-benzofluorene-fluorene group, a benzofluorene group, a dibenzofluorene group, a phenanthrene group, an anthracene group, a dibenzofuran group, a dibenzothiophene group, a dibenzosilole group, and a carbazole group; and

a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, a spiro-benzofluorene-fluorene group, a benzofluorene group, a dibenzofluorene group, a phenanthrene group, an anthracene group, a dibenzofuran group, a dibenzothiophene group, a dibenzosilole group, and a carbazole group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, —Si(Q_{31})(Q_{32})(Q_{33}), and —B(Q_{31})(Q_{32}).

a_1 to a_3 may each independently be 0 or 1.

Ar_1 and Ar_2 may each independently be selected from:

a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a carbazolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzonaphthofuranyl group, a dinaphthofuranyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a benzonaphthosilolyl group, and a dinaphthosilolyl group; and

a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a carbazolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzonaphthofuranyl group, a dinaphthofuranyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a benzonaphthosilolyl group, and a dinaphthosilolyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, and —Si(Q_{31})(Q_{32})(Q_{33}),

b_1 and b_2 may each be 1, and

R_1 to R_{20} may each independently be selected from:

a group represented by Formula 2;

hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a C_1 - C_{20} alkyl group, and a C_1 - C_{20} alkoxy group;

a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group;

a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, and —Si(Q_{31})(Q_{32})(Q_{33}); and

—Si(Q_1)(Q_2)(Q_3), B(Q_1)(Q_2), —C(=O)(Q_1), —S(=O)₂(Q_1), and —P(=O)(Q_1)(Q_2),

wherein Q_1 to Q_3 and Q_{31} to Q_{33} may each independently be selected from a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

In an implementation, in Formulae 1 and 2,

L_1 to L_3 may each independently be selected from:

a benzene group; and

a benzene group, substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group,

a_1 to a_3 may each be 0 or 1,

Ar_1 and Ar_2 may each independently be selected from:

a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a dibenzofuranyl group, and a dibenzothiophenyl group; and

a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, and —Si(Q_{31})(Q_{32})(Q_{33}),

b_1 and b_2 may each be 1, and

R_1 to R_{20} may each independently be selected from:

a group represented by Formula 2;

hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a C_1 - C_{20} alkyl group, and a C_1 - C_{20} alkoxy group;

a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group;

a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, and —Si(Q_{31})(Q_{32})(Q_{33}); and

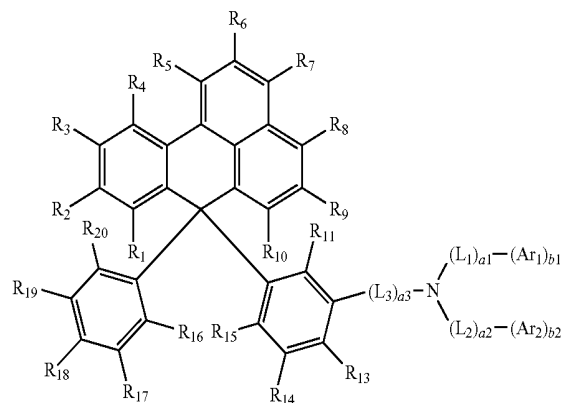
—Si(Q_1)(Q_2)(Q_3), B(Q_1)(Q_2), —C(=O)(Q_1), —S(=O)₂(Q_1), and —P(=O)(Q_1)(Q_2),

wherein Q_1 to Q_3 and Q_{31} to Q_{33} may each independently be selected from a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

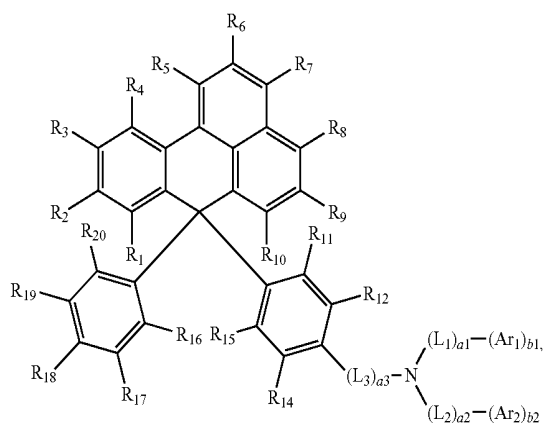
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In an implementation, the condensed cyclic compound represented by Formula 1 may be represented by one of the following Formula 1A or 1B.

<Formula 1A>



<Formula 1B>



In Formulae 1A and 1B, L_1 to L_3 , a_1 to a_3 , Ar_1 , Ar_2 , b_1 , b_2 , and R_1 to R_{20} are the same as described above with respect to Formula 1.

In an implementation, in Formulae 1A and 1B, L_1 to L_3 may each independently be selected from:

a benzene group, substituted with at least one selected from deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group,

a_1 to a_3 may each be 0 or 1,

Ar_1 and Ar_2 may each independently be selected from:

a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a dibenzofuranyl group, and a dibenzothiophenyl group; and

a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, each substituted with at least one selected from deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, and $-Si(Q_{31})(Q_{32})(Q_{33})$.

b_1 and b_2 may each be 1, and

R_1 to R_{20} may each independently be selected from:

hydrogen, deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, a C_1 - C_{20} alkyl group, and a C_1 - C_{20} alkoxy group;

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a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group;

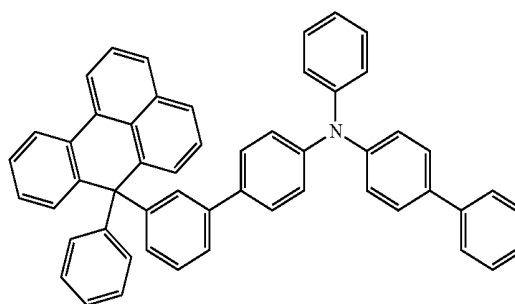
a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group, each substituted with at least one selected from deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, and $-Si(Q_{31})(Q_{32})(Q_{33})$; and $-Si(Q_1)(Q_2)(Q_3)$, $B(Q_1)(Q_2)$, $-C(=O)(Q_1)$, $-S(=O)_2(Q_1)$, and $-P(=O)(Q_1)(Q_2)$,

wherein Q_1 to Q_3 and Q_{31} to Q_{33} may each independently be selected from a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

In an implementation, the condensed cyclic compound represented by Formula 1 may be one of the following Compounds 1 to 37.

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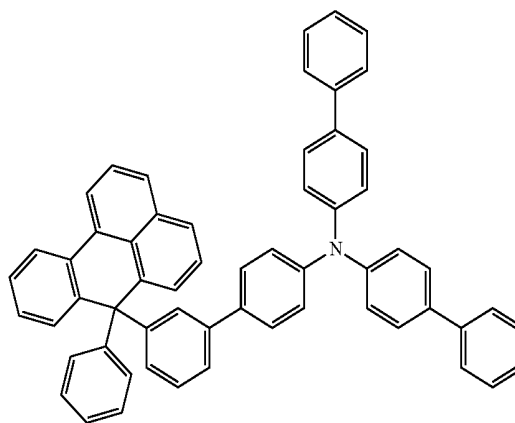
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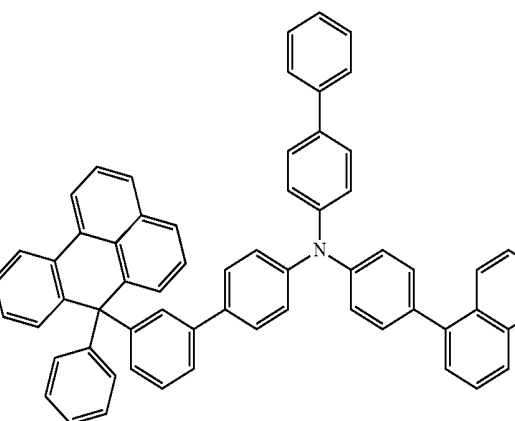
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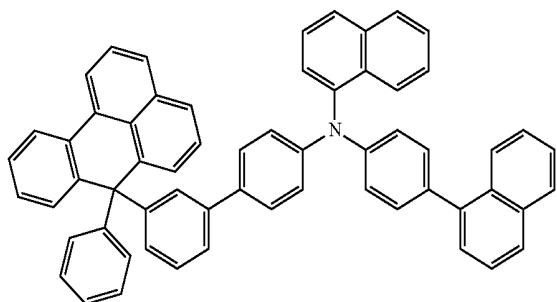


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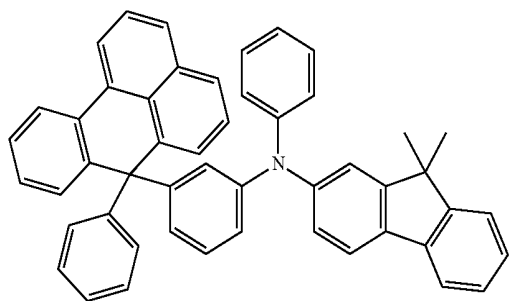


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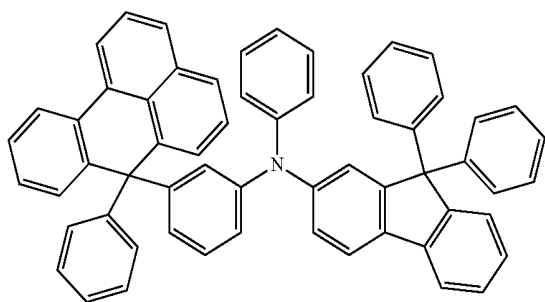


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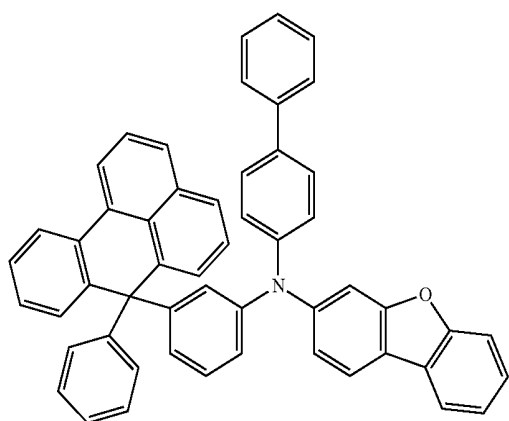


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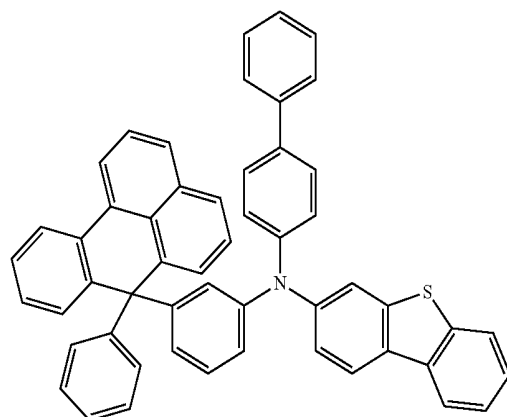
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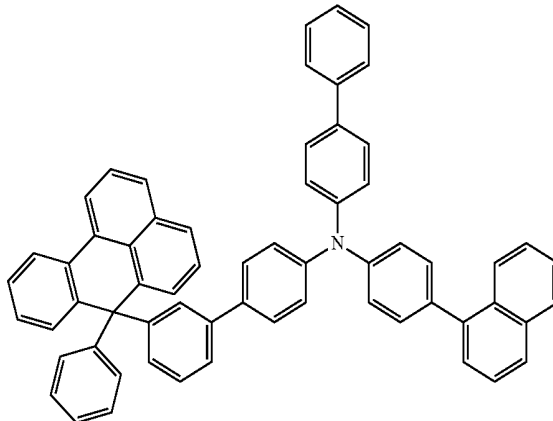
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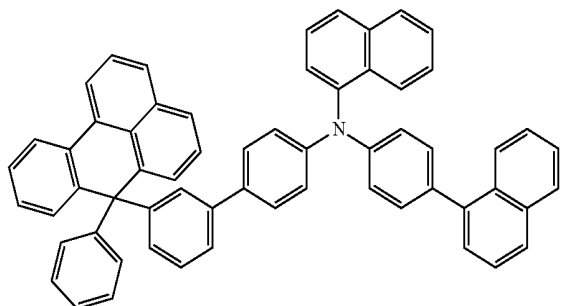
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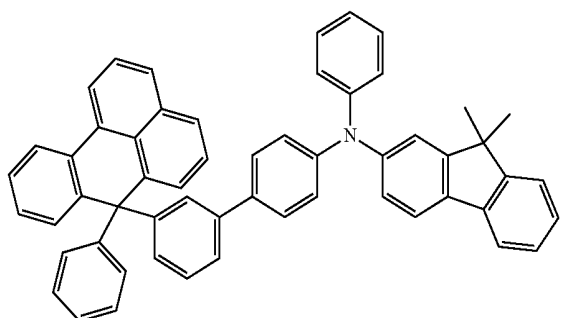


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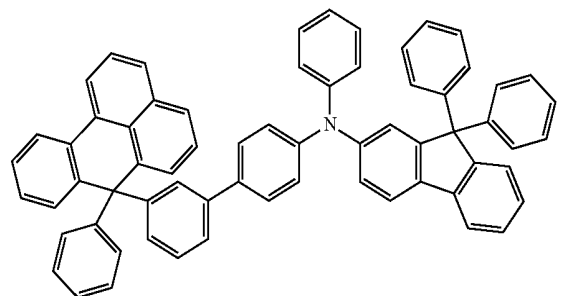
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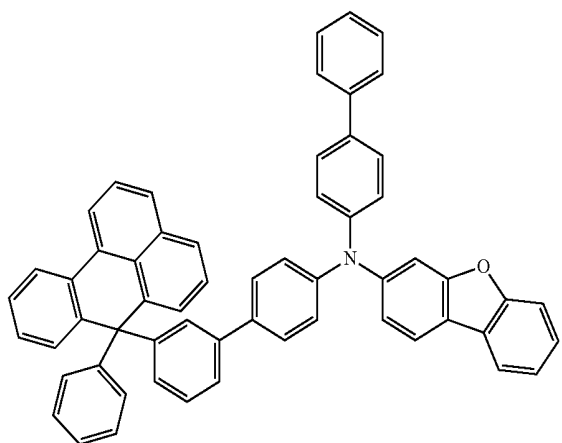


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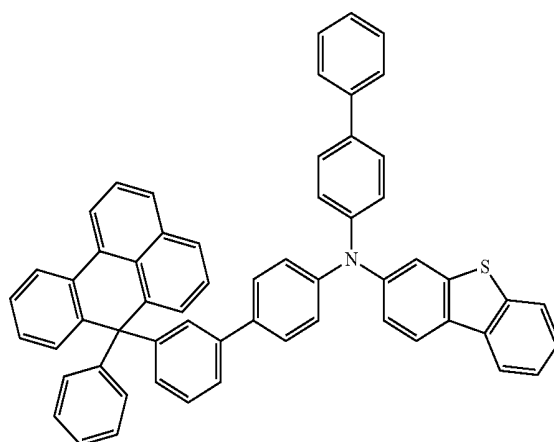
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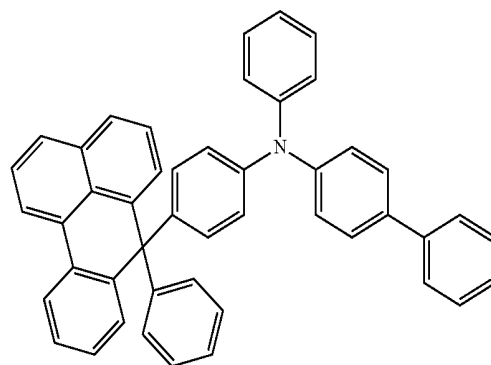
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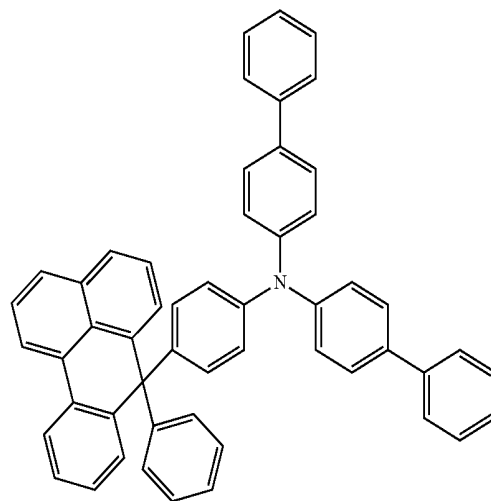
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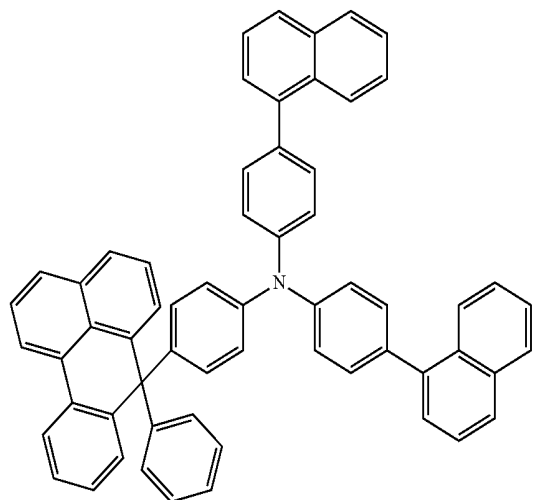
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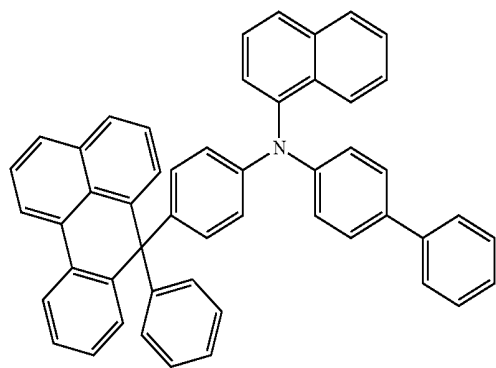
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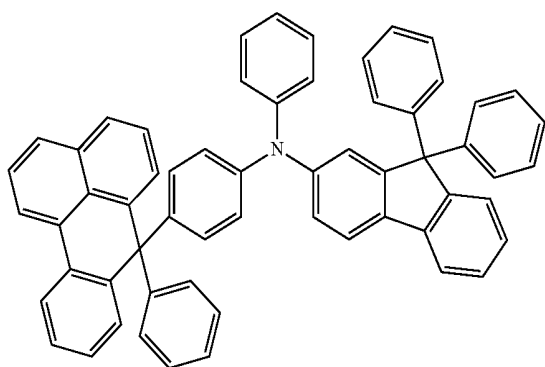
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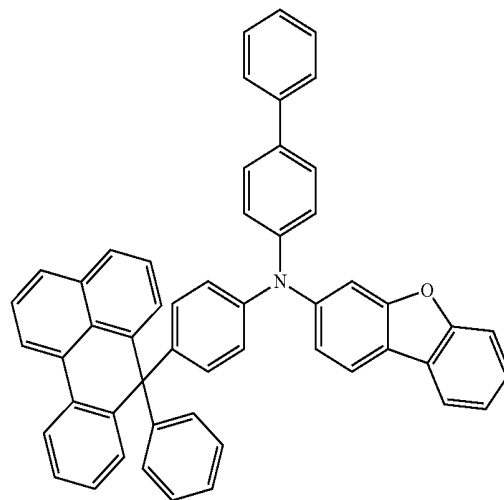
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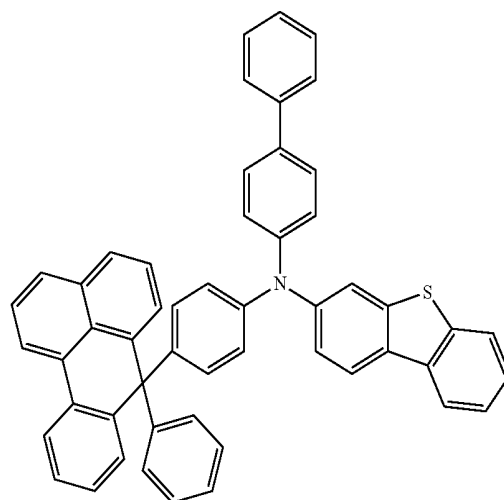
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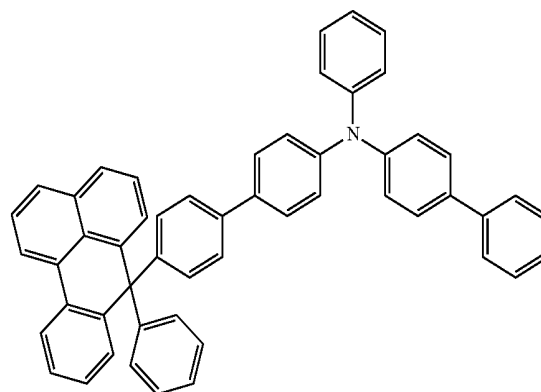
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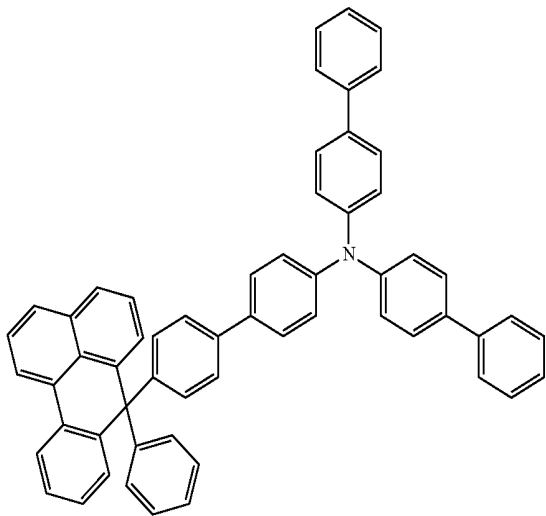
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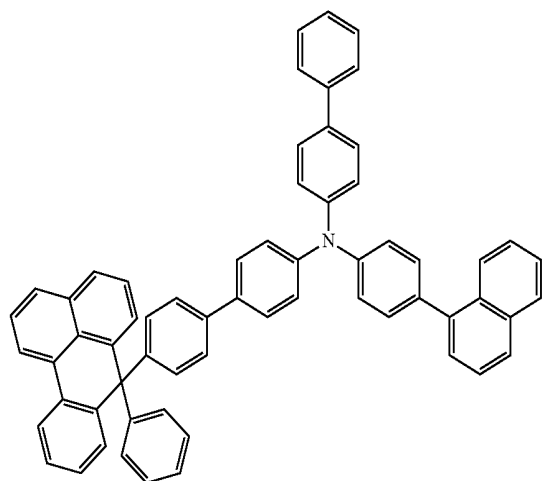
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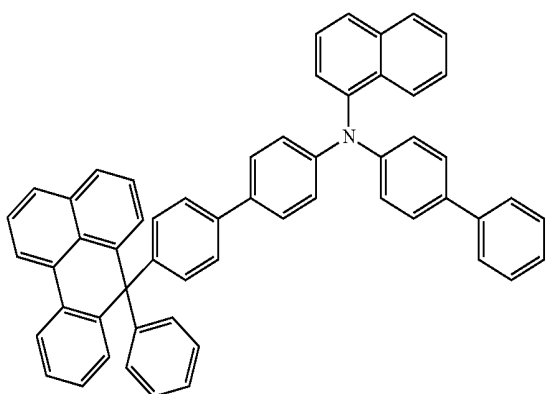
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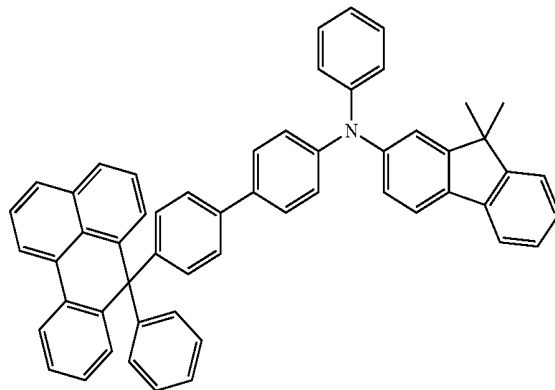
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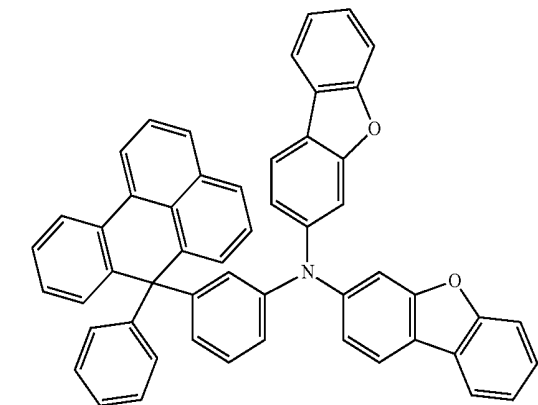
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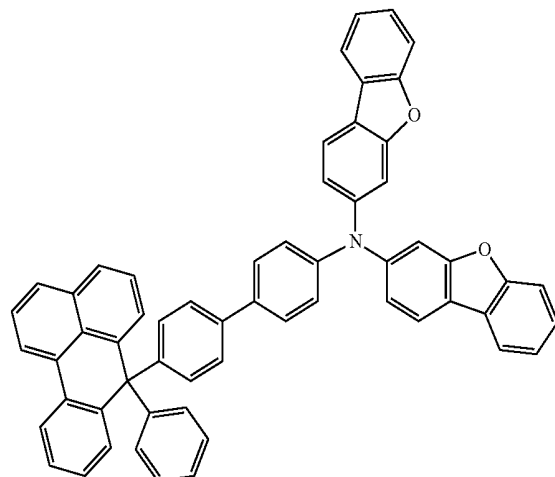
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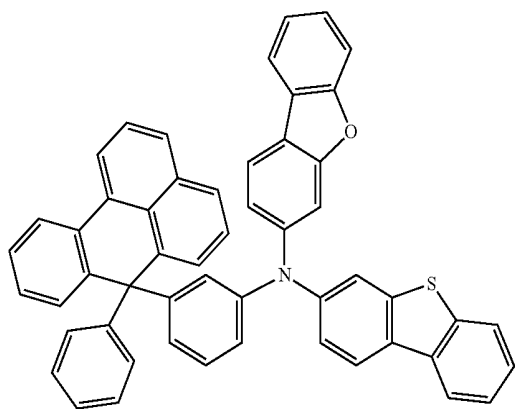
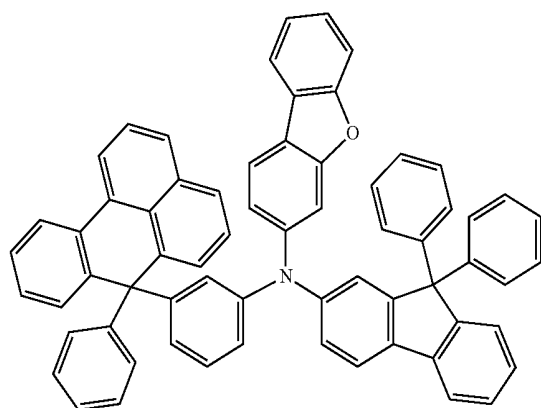
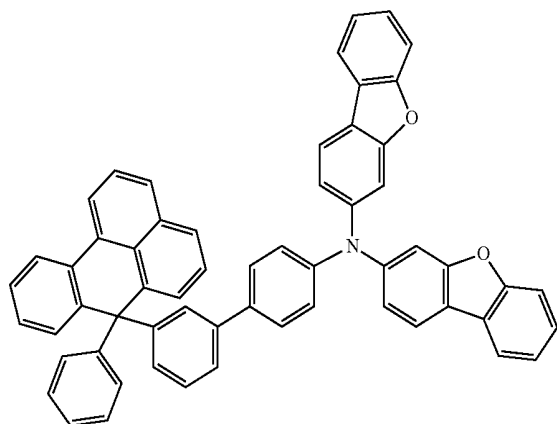
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At least one selected from R_1 to R_{20} in the condensed cyclic compound represented by Formula 1 may be a group represented by Formula 2. For example, Formula 1 may have a single group represented by Formula 2. A benzanthracene core substituted with a phenyl group in the condensed cyclic compound represented by Formula 1 may have high charge resistance and high rigidity, inter-molecular stacking may increase, and a glass transition temperature and a melting point may increase. Accordingly, heat resistance to Joule heating, occurring inside an organic layer or between an organic layer and an electrode, and resistance to high temperature environments may increase. Thus, an organic light-emitting device including the condensed cyclic compound represented by Formula 1 may have high durability during preserving (e.g., storage) and driving. Also, the condensed cyclic compound represented by Formula 1 may

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35 have a relatively high charge (hole or electron) transport capability, and an exciton formation rate may increase within an emission layer in an organic light-emitting device including the condensed cyclic compound represented by
5 Formula 1. Accordingly, the organic light-emitting device may have a low driving voltage, high efficiency, and a long lifespan.

A synthesis method for the condensed cyclic compound represented by Formula 1 may be understood by referring to
10 the following examples.

At least one condensed cyclic compound represented by Formula 1 may be used or included between a pair of electrodes constituting an organic light-emitting device. For example, the condensed cyclic compound may be included
15 in at least one layer in a hole transport region, an electron transport region, or an emission layer. In an implementation, the condensed cyclic compound of Formula 1 may be used as a material for a capping layer located outside a pair of electrodes of an organic light-emitting device.

20 According to another aspect of embodiments, an organic light-emitting device may include a first electrode, a second electrode, and an organic layer between the first electrode and the second electrode, the organic layer including an emission layer and at least one condensed cyclic compound
25 described above (e.g., represented by Formula 1).

The expression “(an organic layer) includes at least one of the condensed cyclic compounds” used herein may include a case in which “(an organic layer) includes identical condensed cyclic compounds represented by Formula 1” and a case in which “(an organic layer) includes two or more
30 different condensed cyclic compounds represented by Formulae 1A and 1B.”

In one or more embodiments, the first electrode may be an anode and the second electrode may be a cathode; the organic layer may further include a hole transport region between the first electrode and the emission layer, and an electron transport region between the emission layer and the second electrode; the hole transport region includes a hole injection layer, a hole transport layer, an emission auxiliary layer, an electron blocking layer, or any combination thereof; and the electron transport region includes a buffer layer, a hole blocking layer, an electron control layer, an electron transport layer, an electron injection layer, or any combination thereof.
37

35 In an implementation, the hole transport region may include at least one of the condensed cyclic compounds described above.

In an implementation, the hole transport region may include a hole transport layer, and the hole transport layer may include the condensed cyclic compound represented by Formula 1.
40

In an implementation, the hole transport region may include a p-dopant. In an implementation, the lowest unoccupied molecular orbital (LUMO) of the p-dopant may be -3.5 eV or less. In an implementation, the p-dopant may include a quinone derivative, a metal oxide, a cyano group-containing compound, or any combination thereof.
45

In an implementation, the electron transport layer may include an alkali metal, an alkaline earth metal, a rare-earth metal, an alkali metal compound, an alkaline earth-metal compound, a rare-earth metal compound, an alkali metal complex, an alkaline earth-metal complex, a rare-earth metal complex, or any combinations thereof.
50

In an implementation, the emission layer may include a dopant and a host, and the host may include at least one selected from an anthracene-based compound, a pyrene-based compound, and a spiro-bifluorene based compound.

The emission layer in the organic light-emitting device may be a first color light-emitting layer. The organic light-emitting device may further include i) at least one second color light-emitting layer or ii) at least one second color light-emitting layer and at least one third color light-emitting layer, between the first electrode and the second electrode. A maximum emission wavelength of the first color light-emitting layer, a maximum emission wavelength of the second color light-emitting layer, and a maximum emission wavelength of the third color light-emitting layer may be identical to or different from each other. The first color light and the second color light may be emitted in the form of mixed light, or the first color light, the second color light, and the third color light may be emitted in the form of mixed light.

In an implementation, the organic light-emitting device may further include a first capping layer disposed in a pathway along which light generated in an emission layer proceeds toward the outside through the first electrode or a second capping layer disposed in a pathway along which light generated in an emission layer proceeds toward the outside through the second electrode. In an implementation the first capping layer or the second capping layer may include at least one of the condensed cyclic compounds represented by Formula 1.

In an implementation, the organic light-emitting device may have i) a stack structure including a first electrode, an organic layer, a second electrode, and a second capping layer which are sequentially stacked in this stated order, ii) a stack structure including a first capping layer, a first electrode, an organic layer, and a second electrode which are sequentially stacked in this stated order, or iii) a stack structure including a first capping layer, a first electrode, an organic layer, a second electrode, and a second capping layer which are sequentially stacked in this stated order, and at least one selected from the first capping layer and the second capping layer may include the condensed cyclic compound.

The term "organic layer" used herein refers to a single layer and/or a plurality of layers disposed between the first electrode and the second electrode of the organic light-emitting device. A material included in the "organic layer" is not limited to an organic material.

[Description of FIG. 1]

FIG. 1 illustrates a schematic view of an organic light-emitting device 10 according to an embodiment. The organic light-emitting device 10 may include a first electrode 110, an organic layer 150, and a second electrode 190.

Hereinafter, the structure of the organic light-emitting device 10 according to an embodiment and a method of manufacturing the organic light-emitting device 10 will be described in connection with FIG. 1.

[First Electrode 110]

In an implementation, a substrate may be additionally disposed under the first electrode 110 or above the second electrode 190. The substrate may be a glass substrate or a plastic substrate, each having excellent mechanical strength, thermal stability, transparency, surface smoothness, ease of handling, and water resistance.

The first electrode 110 may be formed by depositing or sputtering a material for forming the first electrode 110 on the substrate. When the first electrode 110 is an anode, the

material for forming a first electrode may be selected from materials with a high work function to facilitate hole injection.

The first electrode 110 may be a reflective electrode, a semi-transmissive electrode, or a transmissive electrode. When the first electrode 110 is a transmissive electrode, a material for forming a first electrode may be selected from, e.g., indium tin oxide (ITO), indium zinc oxide (IZO), tin oxide (SnO₂), zinc oxide (ZnO), and any combination thereof. When the first electrode 110 is a semi-transmissive electrode or a reflective electrode, as a material for forming the first electrode 110, e.g., magnesium (Mg), silver (Ag), aluminum (Al), aluminum-lithium (Al—Li), calcium (Ca), magnesium-indium (Mg—In), magnesium-silver (Mg—Ag), or any combination thereof may be used.

The first electrode 110 may have a single-layered structure, or a multi-layered structure including two or more layers. In an implementation, the first electrode 110 may have a three-layered structure of ITO/Ag/ITO.

[Organic Layer 150]

The organic layer 150 may be disposed on the first electrode 110. The organic layer 150 may include an emission layer.

The organic layer 150 may further include a hole transport region between the first electrode 110 and the emission layer, and an electron transport region between the emission layer and the second electrode 190.

[Hole Transport Region in Organic Layer 150]

The hole transport region may have, e.g., i) a single-layered structure including a single layer including a single material, ii) a single-layered structure including a single layer including a plurality of different materials, or iii) a multi-layered structure having a plurality of layers including a plurality of different materials.

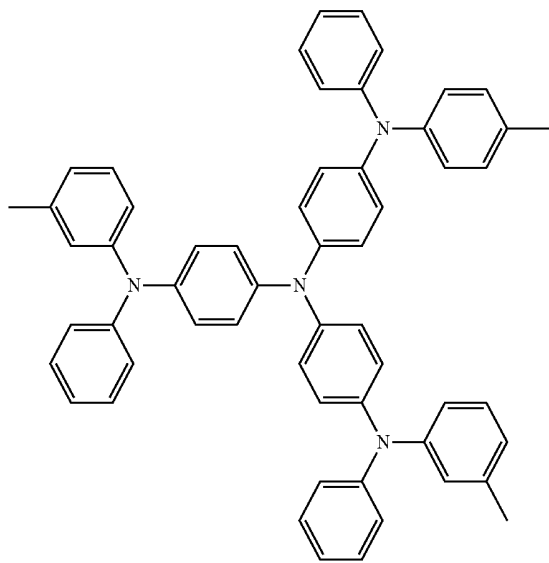
The hole transport region may include at least one layer selected from a hole injection layer (HIL), a hole transport layer (HTL), an emission auxiliary layer, and an electron blocking layer (EBL).

In an implementation, the hole transport region may have a single-layered structure including a single layer including a plurality of different materials, or a multi-layered structure having a hole injection layer/hole transport layer structure, a hole injection layer/hole transport layer/emission auxiliary layer structure, a hole injection layer/emission auxiliary layer structure, a hole transport layer/emission auxiliary layer structure, or a hole injection layer/hole transport layer/electron blocking layer structure, wherein for each structure, constituting layers are sequentially stacked from the first electrode 110 in this stated order.

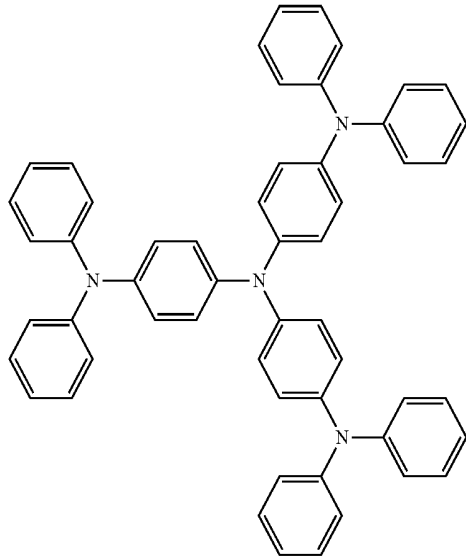
In an implementation, the hole transport region may further include at least one of the condensed cyclic compounds (e.g., represented by Formula 1). For example, the hole transport region may include a hole transport layer, and the hole transport layer may include at least one of the condensed cyclic compounds.

The hole transport region may include at least one selected from m-MTDATA, TDATA, 2-TNATA, NPB (NPD), β-NPB, TPD, Spiro-TPD, Spiro-NPB, methylated-NPB, TAPC, HMTDP, 4,4',4''-tris(N-carbazolyl)triphenylamine (TCTA), polyaniline/dodecylbenzenesulfonic acid (PANI/DBSA), PEDOT/PSS (poly(3,4-ethylenedioxythiophene)/poly(4-styrenesulfonate)), polyaniline/camphor sulfonic acid (PANI/CSA), polyaniline/poly(4-styrenesulfonate) (PANI/PSS), a compound represented by Formula 201, and a compound represented by Formula 202:

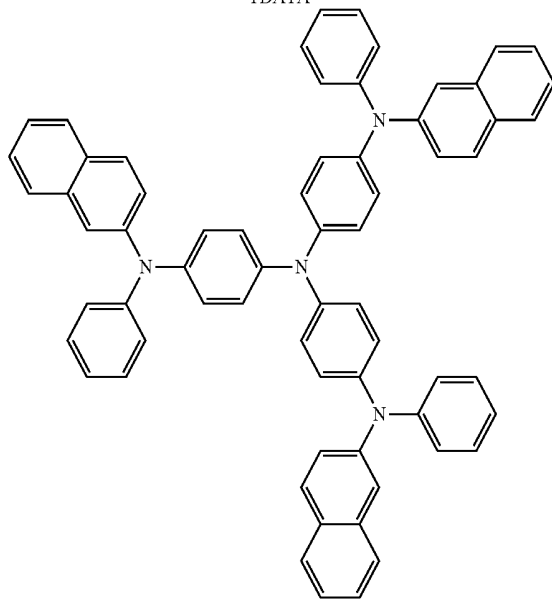
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m-MTDATA



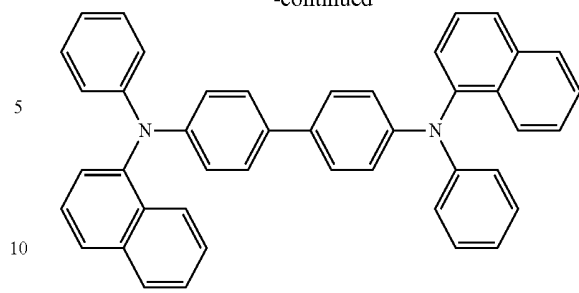
TDATA



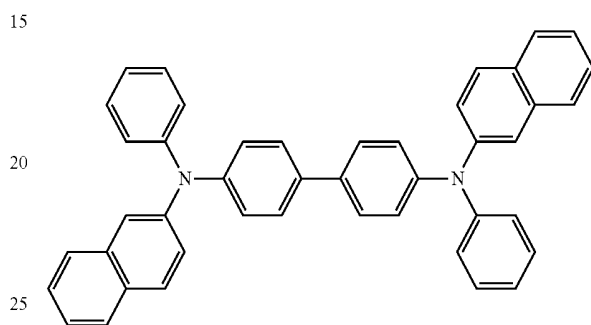
2-TNATA

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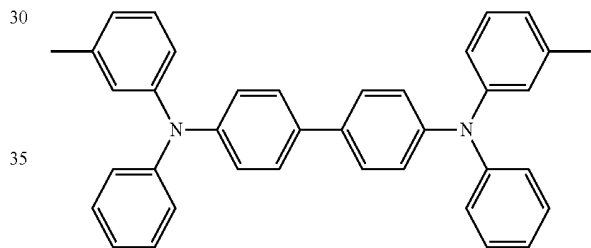
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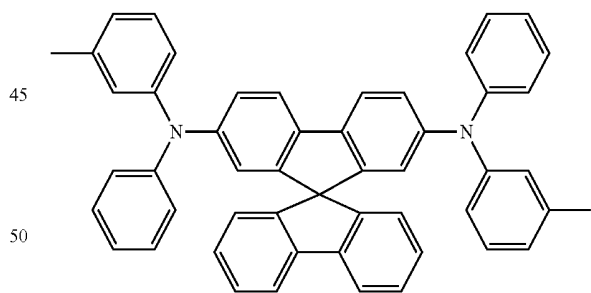
NPB



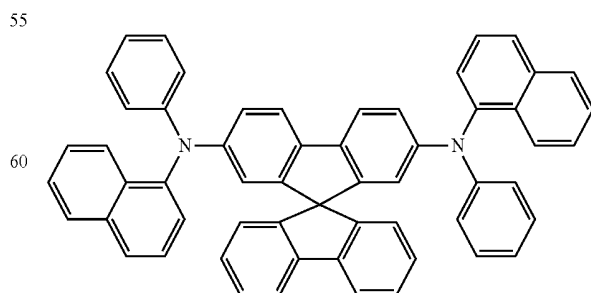
β -NPB



TPD

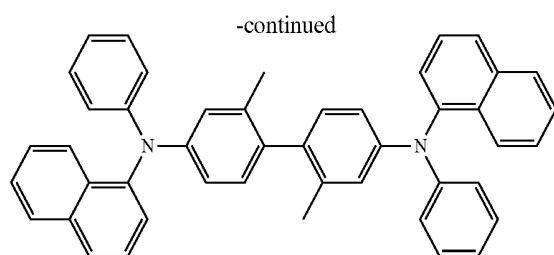


Spiro-TPD

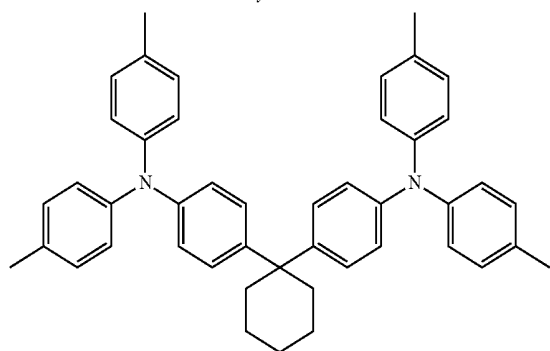


Spiro-NPB

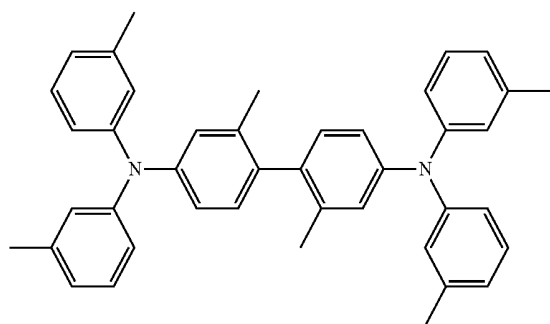
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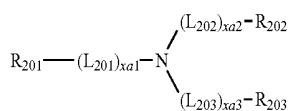
methylated NPB



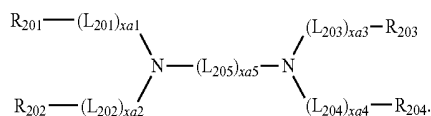
TAPC



HMTPD



<Formula 201>



<Formula 202>

In Formulae 201 and 202,

L_{201} to L_{204} may each independently be selected from a substituted or unsubstituted C_3 - C_{10} cycloalkylene group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkylene group, a substituted or unsubstituted C_3 - C_{10} cycloalkenylene group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkenylene group, a substituted or unsubstituted C_6 - C_{60} arylene group, a substituted or unsubstituted C_1 - C_{60} heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group,

L_{205} may be selected from $^*-\text{O}-^*$, $^*-\text{S}-^*$, $^*-\text{N}(\text{Q}_{201})-^*$, a substituted or unsubstituted C_1 - C_{20} alkylene group, a substituted or unsubstituted C_2 - C_{20} alkenylene group, a substituted or unsubstituted C_3 - C_{10} cycloalkylene group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkylene group, a substituted or unsubstituted C_3 - C_{10} cycloalkenylene group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkenylene group, a substituted or unsubstituted

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C_1 - C_{10} heterocycloalkenylene group, a substituted or unsubstituted C_6 - C_{60} arylene group, a substituted or unsubstituted C_1 - C_{60} heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group,

xa1 to xa4 may each independently be an integer of 0 to 3,

xa5 may be an integer of 1 to 10, and

R_{201} to R_{204} and Q_{201} may each independently be selected from a substituted or unsubstituted C_3 - C_{10} cycloalkyl group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3 - C_{10} cycloalkenyl group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6 - C_{60} aryl group, a substituted or unsubstituted C_6 - C_{60} aryloxy group, a substituted or unsubstituted C_6 - C_{60} arylthio group, a substituted or unsubstituted C_1 - C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group.

For example, in Formula 202, R_{201} and R_{202} may optionally be linked via a single bond, a dimethyl-methylene group, or a diphenyl-methylene group, and R_{203} and R_{204} may optionally be linked via a single bond, a dimethyl-methylene group, or a diphenyl-methylene group.

In one or more embodiments, in Formulae 201 and 202,

L_{201} to L_{205} may each independently be selected from:

a phenylene group, a pentalenylene group, an indenylene group, a naphthalenylene group, an azulenylene group, a heptalenylene group, an indenylene group, an acenaphthalenylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenalenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthrenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a naphthacenylene group, a picenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pentacenylene group, a rubicenylene group, a coronenylene group, an ovalenylene group, a thiophenylene group, a furanylene group, a carbazolylene group, an indolylene group, an isoindolylene group, a benzofuranylene group, a benzothiophenylene group, a dibenzofuranylene group, a dibenzothiophenylene group, a benzocarbazolylene group, a dibenzocarbazolylene group, a dibenzosilolylene group, and a pyridinylene group; and

a phenylene group, a pentalenylene group, an indenylene group, a naphthalenylene group, an azulenylene group, a heptalenylene group, an indacenylene group, an acenaphthalenylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenalenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthrenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a naphthacenylene group, a picenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pentacenylene group, a rubicenylene group, a coronenylene group, an ovalenylene group, a thiophenylene group, a furanylene group, a carbazolylene group, an indolylene group, an isoindolylene group, a benzofuranylene group, a benzothiophenylene group, a dibenzofuranylene group, a dibenzothiophenylene group, a benzocarbazolylene group, a dibenzocarbazolylene group, a dibenzosilolylene group, and a pyridinylene group;

wherein Q_{31} to Q_{33} may each independently be selected from a C_1 - C_{10} alkyl group, a C_1 - C_{10} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group, each substituted with at least one selected from deuterium, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group,

a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a phenyl group substituted with a C₁-C₁₀ alkyl group, a phenyl group substituted with —F, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacacenyl group, a pentacacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, —Si(Q₃₁)(Q₃₂)(Q₃₃), and —N(Q₃₁)(Q₃₂).

In one or more embodiments, xa1 to xa4 may each independently be 0, 1, or 2.

In one or more embodiments, xa5 may be 1, 2, 3, or 4.

In one or more embodiments, R₂₀₁ to R₂₀₄ and Q₂₀₁ may each independently be selected from a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacacenyl group, a pentacacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, and a pyridinyl group; and

a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacacenyl group, a pentacacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, and a pyridinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a phenyl group substituted with a C₁-C₁₀ alkyl group, a phenyl group substituted with —F, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl

group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacacenyl group, a pentacacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, —Si(Q₃₁)(Q₃₂)(Q₃₃), and —N(Q₃₁)(Q₃₂);

wherein Q₃₁ to Q₃₃ are the same as described above.

In one or more embodiments, at least one from R₂₀₁ to R₂₀₃ in Formula 201 may be selected from:

a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group; and

a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a phenyl group substituted with a C₁-C₁₀ alkyl group, a phenyl group substituted with —F, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group.

In one or more embodiments, in Formula 202, i) R₂₀₁ and R₂₀₂ may be linked via a single bond, and/or ii) R₂₀₃ and R₂₀₄ may be linked via a single bond.

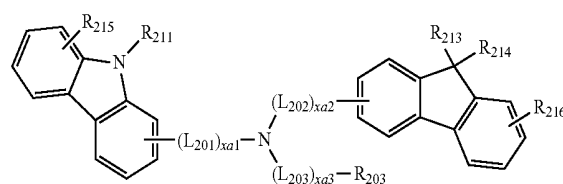
In one or more embodiments, at least one from R₂₀₁ to R₂₀₄ in Formula 202 may be selected from:

a carbazolyl group; and

a carbazolyl group substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a phenyl group substituted with a C₁-C₁₀ alkyl group, a phenyl group substituted with —F, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group.

The compound represented by Formula 201 may be represented by Formula 201A:

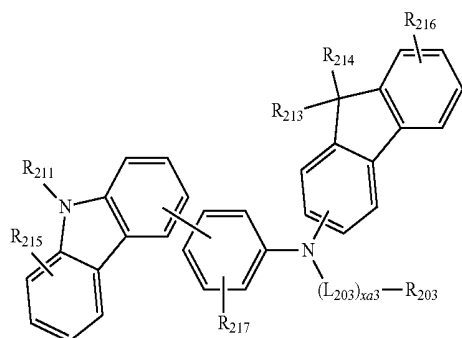
<Formula 201A>



In one or more embodiments, the compound represented by Formula 201 may be represented by Formula 201A(1) below:

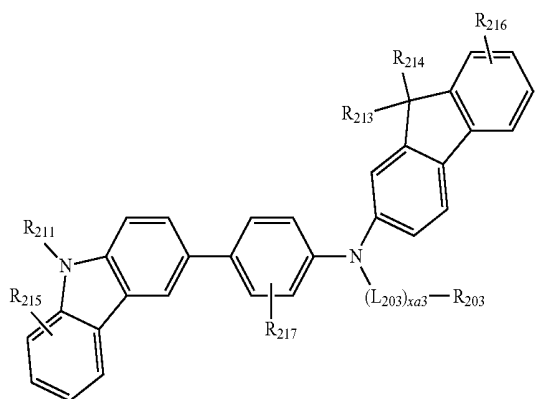
55

<Formula 201A(1)>



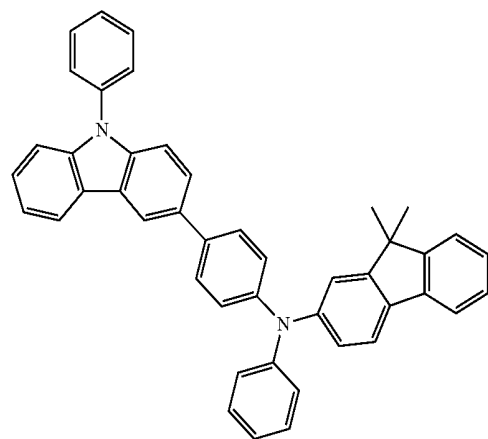
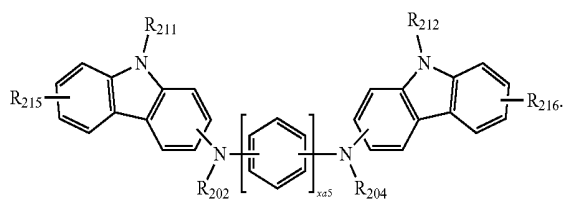
In one or more embodiments, the compound represented by Formula 201 may be represented by Formula 201A-1 below:

<Formula 201A-1>

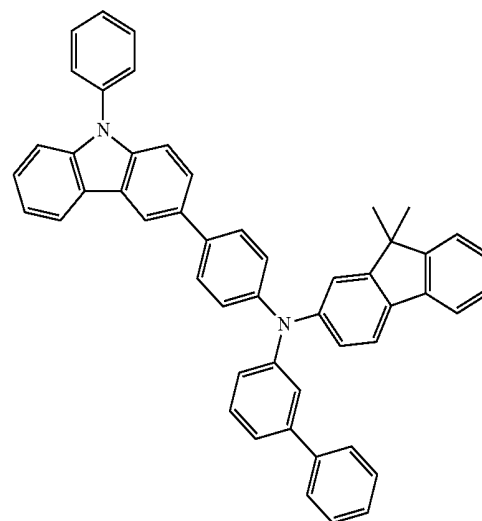


In one or more embodiments, the compound represented by Formula 202 may be represented by Formula 202A:

<Formula 202A>



HT1

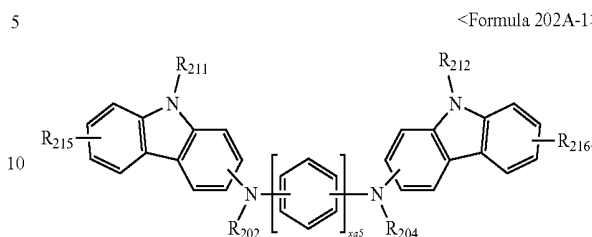


HT2

56

In one or more embodiments, the compound represented by Formula 202 may be represented by Formula 202A-1:

<Formula 202A-1>



15 In Formulae 201A, 201A(1), 201A-1, 202A, and 202A-1,

L₂₀₁ to L₂₀₃, xa1 to xa3, xa5, and R₂₀₂ to R₂₀₄ are the same as described above,

20 R₂₁₁ and R₂₁₂ may be understood by referring to the description provided herein in connection with R₂₀₃, and

25 R₂₁₃ to R₂₁₇ may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a phenyl group substituted with a C₁-C₁₀ alkyl group, a phenyl group substituted with —F, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthrenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, and a pyridinyl group.

45 The hole transport region may include at least one compound selected from Compounds HT1 to HT39:

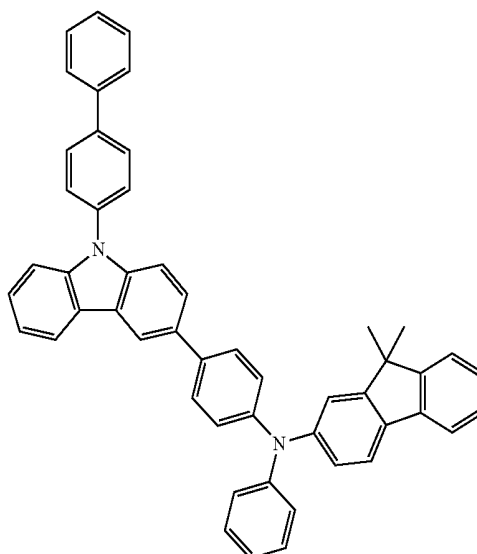
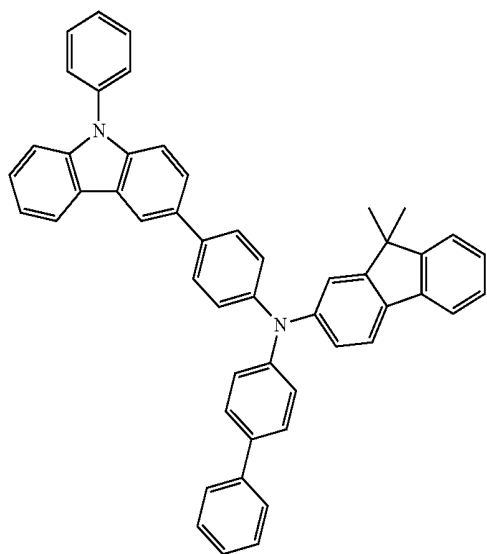
57

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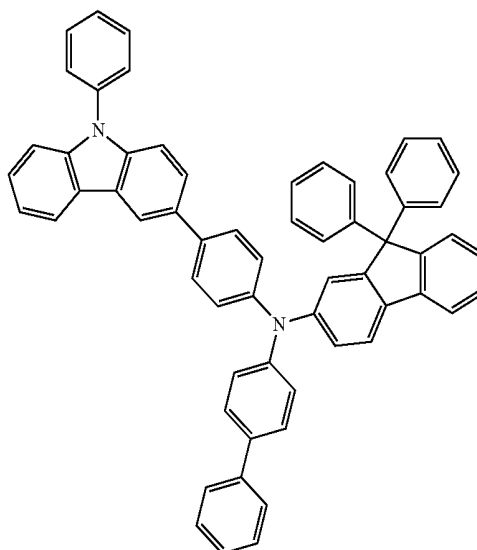
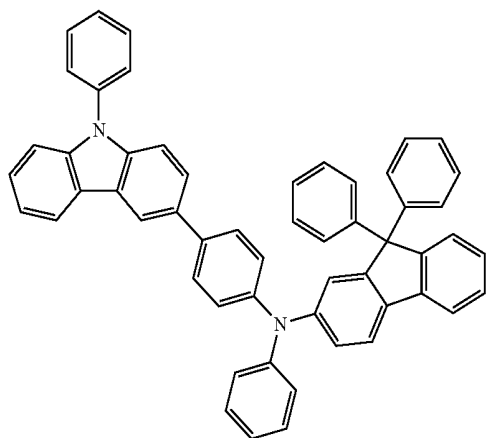
HT3

HT4



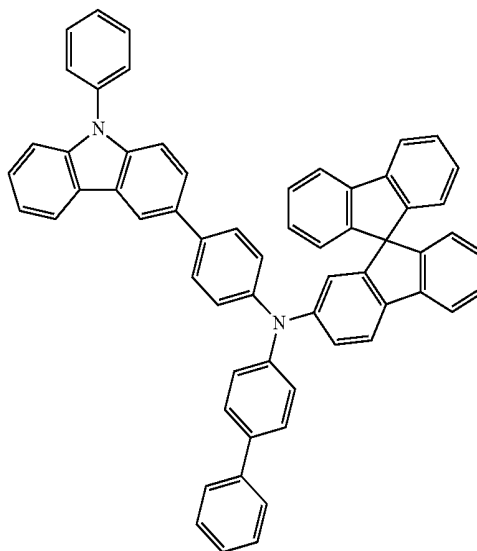
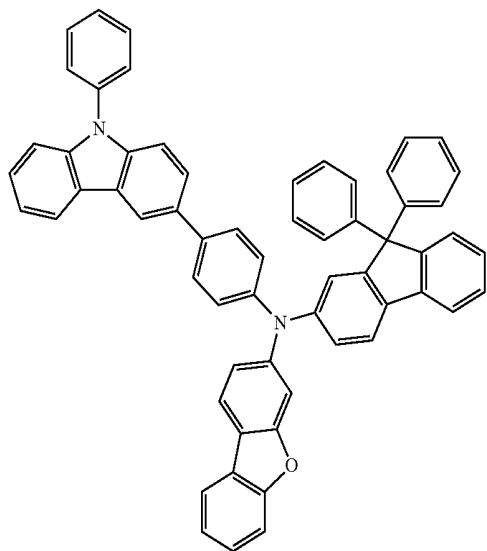
HT5

HT6

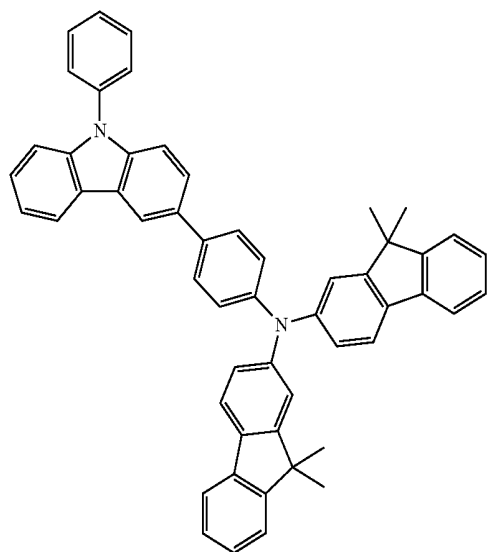


HT7

HT8

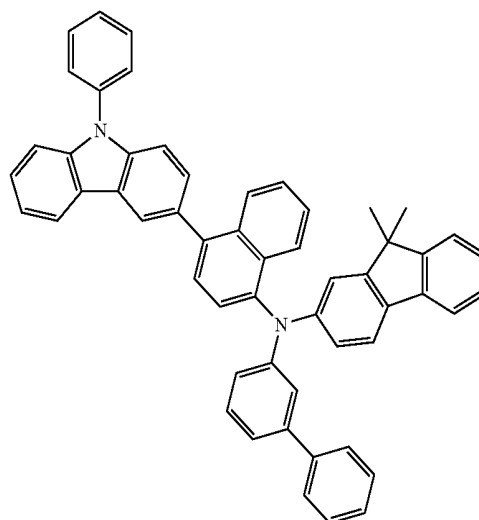


59



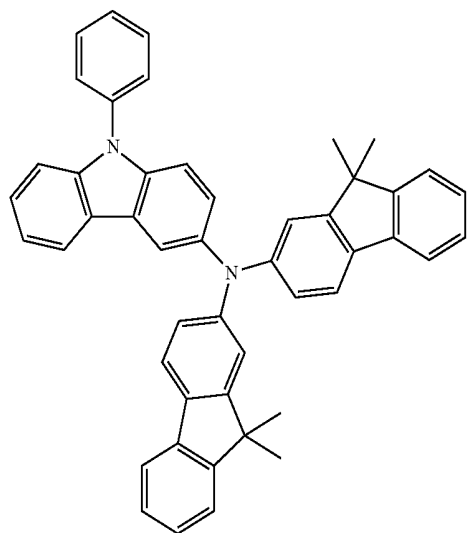
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HT9

60

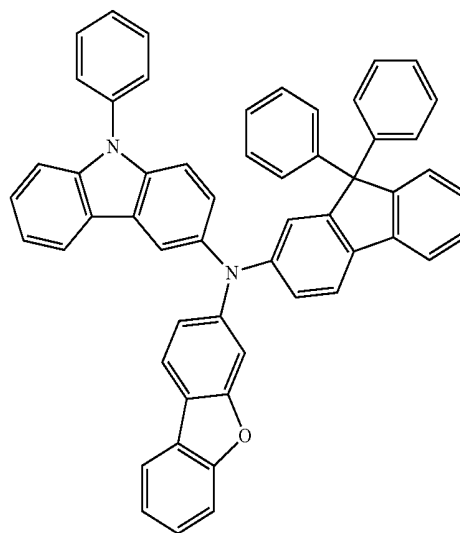


HT10

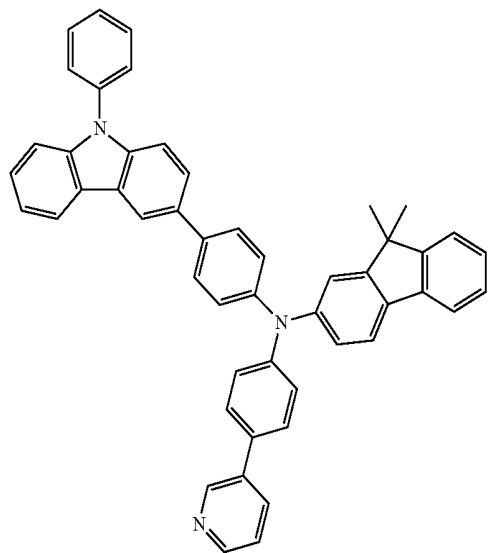
HT11



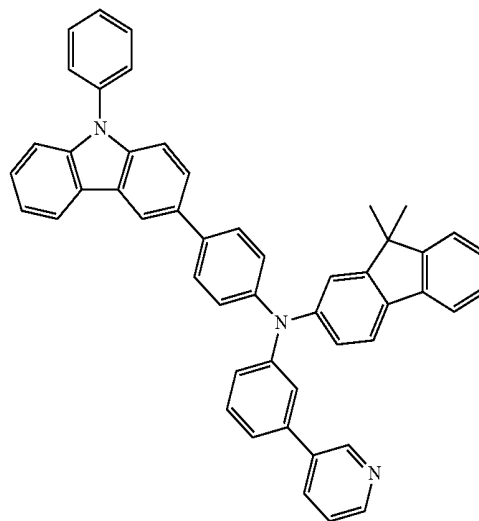
HT12



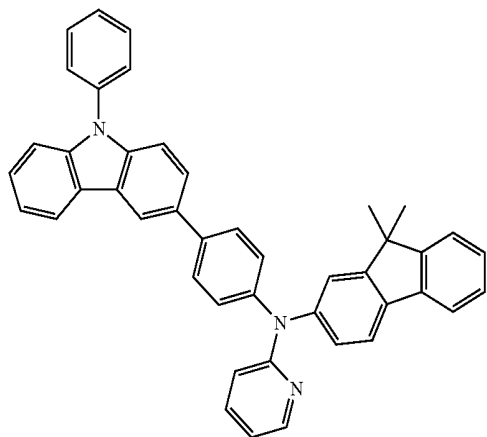
HT13



HT14

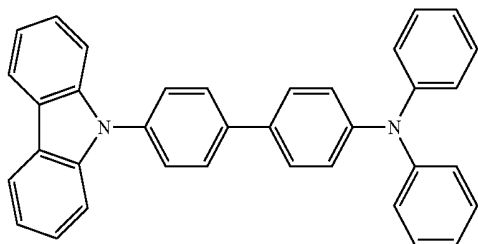


61



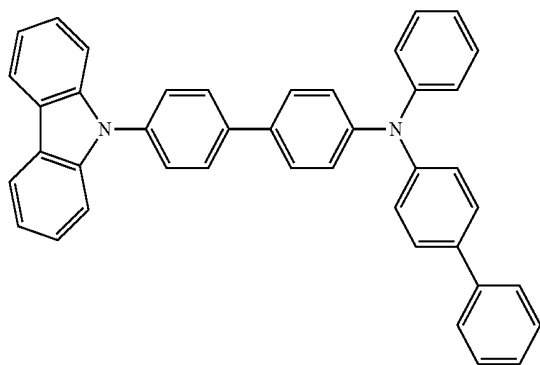
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HT15

62

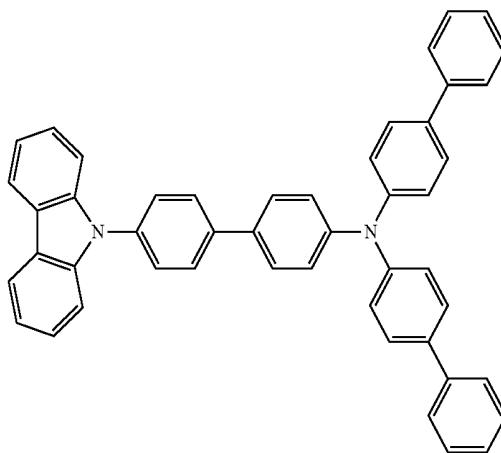


HT16

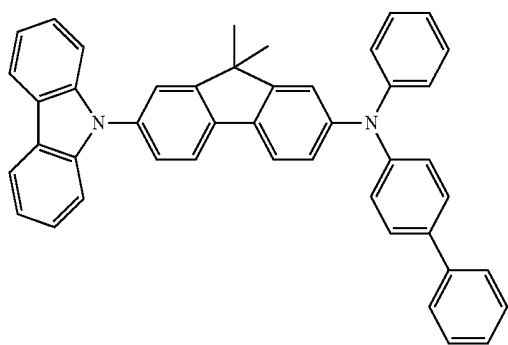
HT17



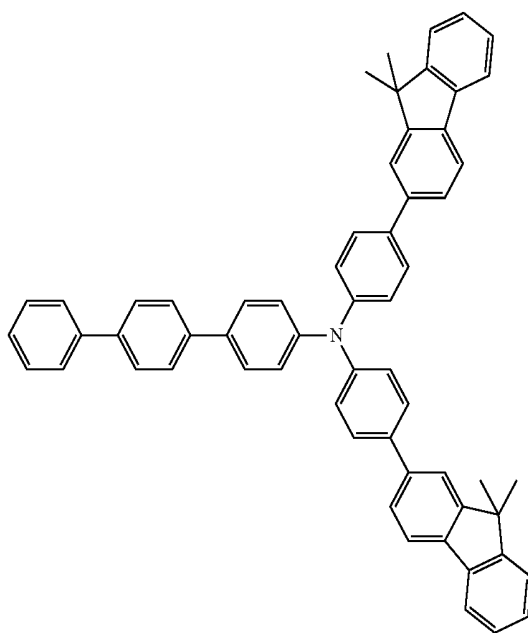
HT18



HT19

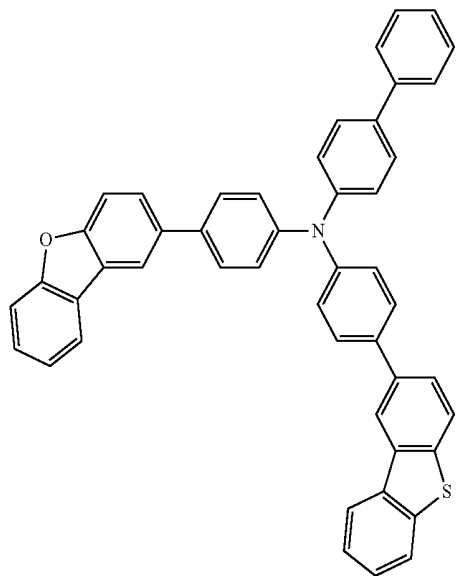


HT20



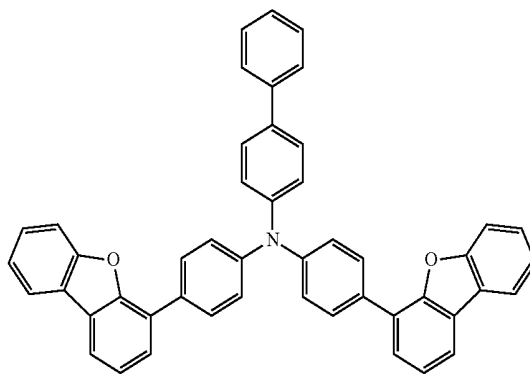
63

-continued
HT21

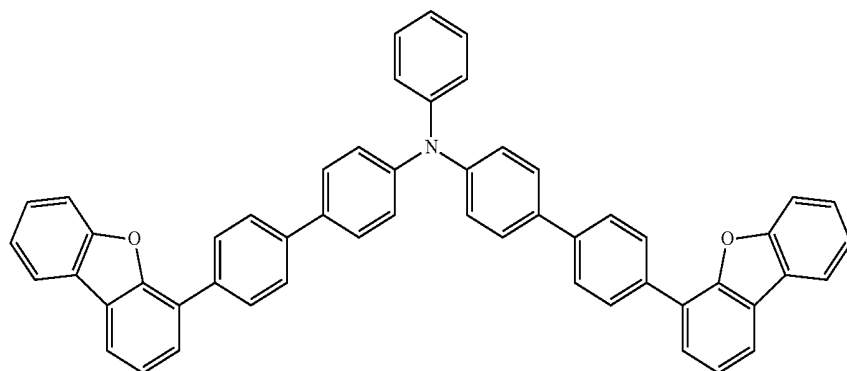


64

HT22

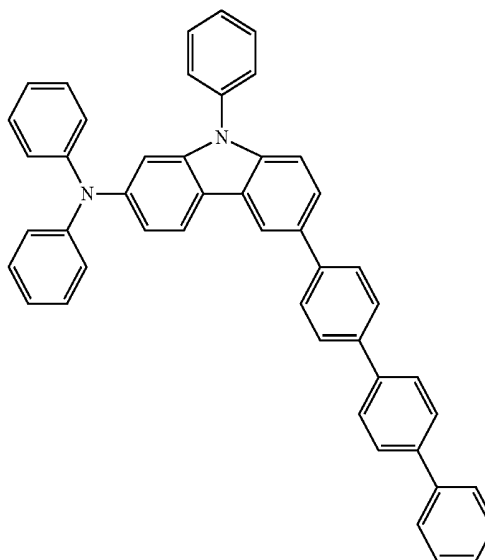
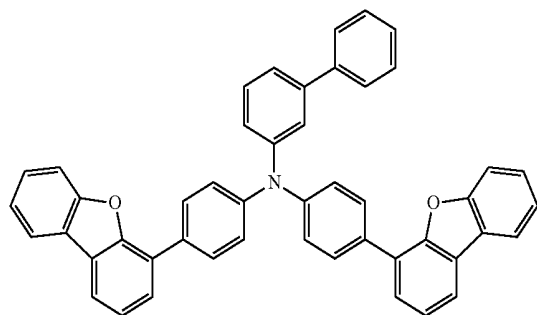


HT23



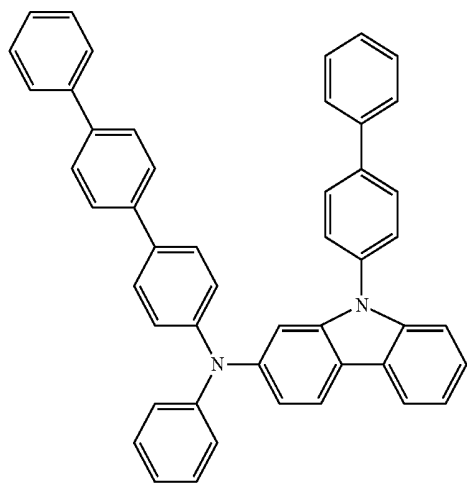
HT24

HT25



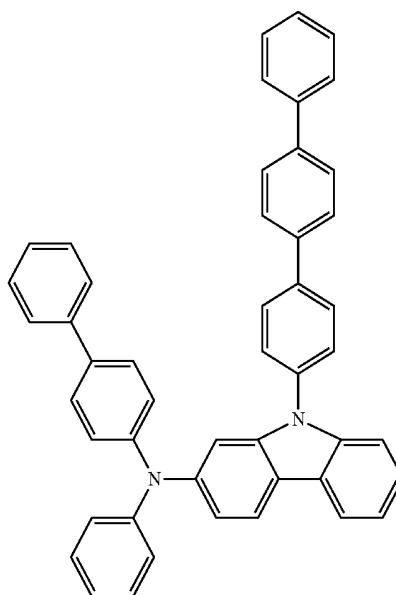
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-continued
HT26

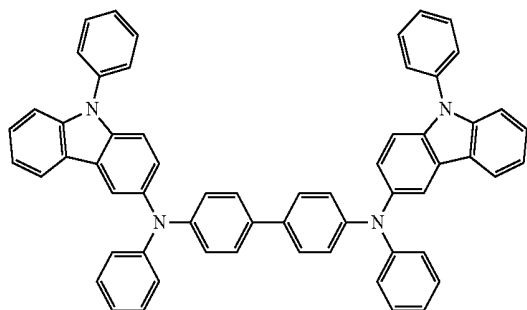


66

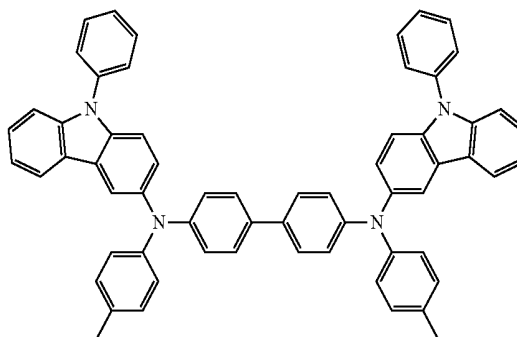
HT27



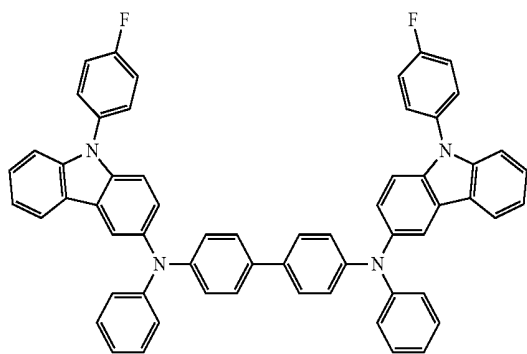
HT28



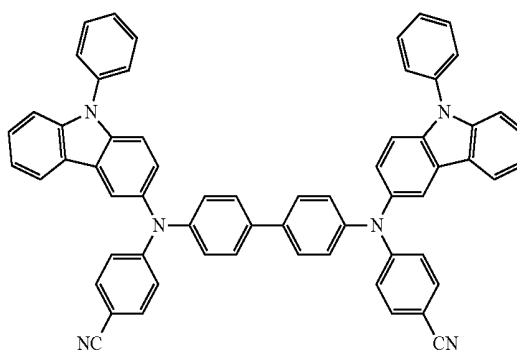
HT29



HT30

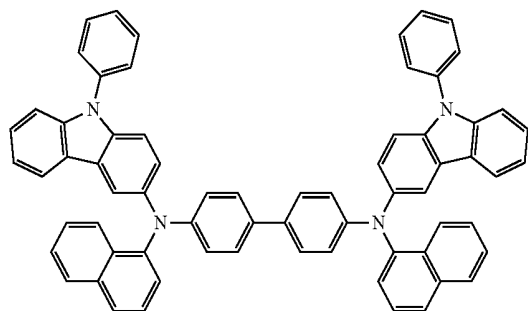


HT31



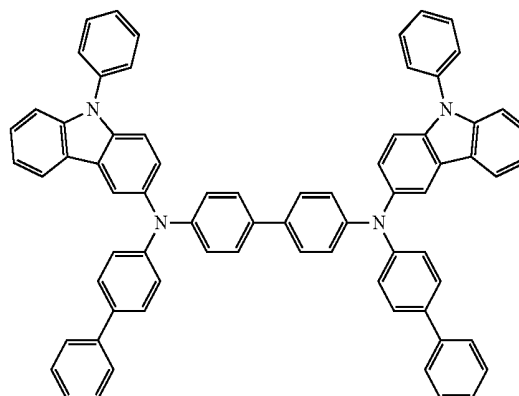
67

-continued
HT32

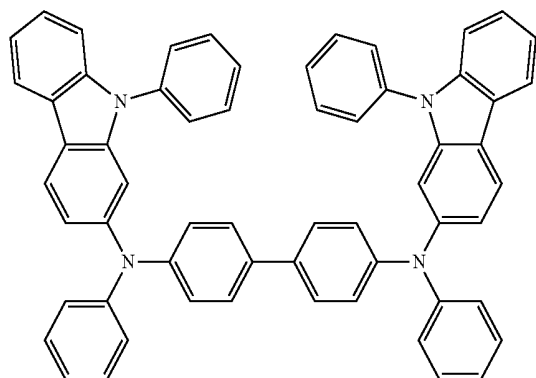


68

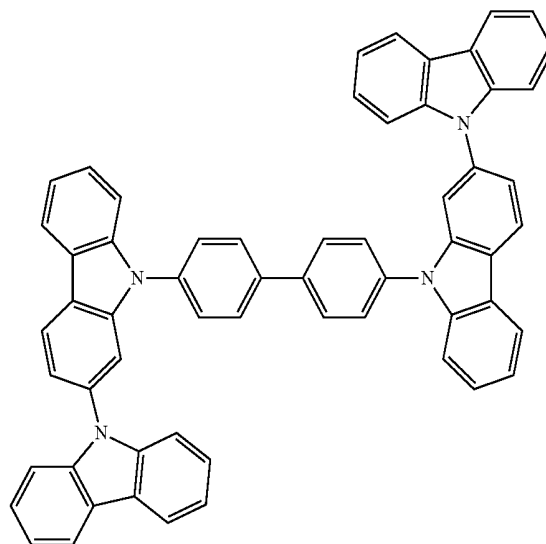
HT33



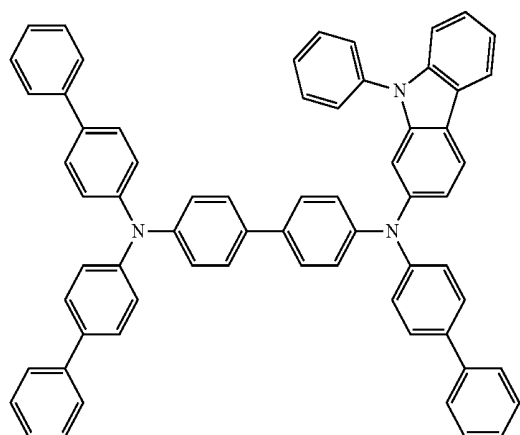
HT34



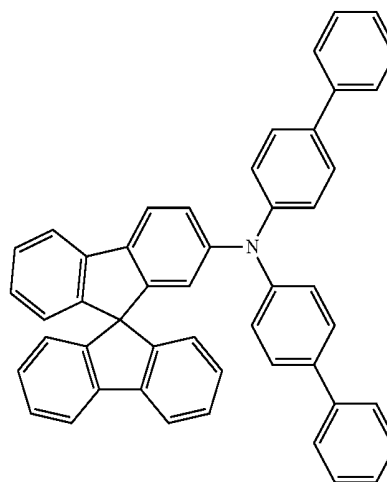
HT35



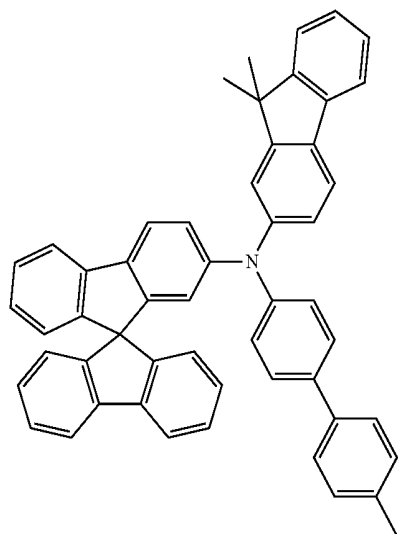
HT36



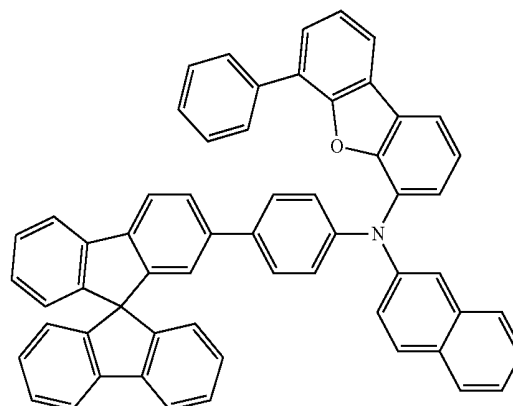
HT37



69

-continued
HT38

70



HT39

In an implementation, a thickness of the hole transport region may be in a range of about 100 Å to about 10,000 Å, e.g., about 100 Å to about 1,000 Å. When the hole transport region includes at least one of a hole injection layer and a hole transport layer, the thickness of the hole injection layer may be in a range of about 100 Å to about 9,000 Å, e.g., about 100 Å to about 1,000 Å, and the thickness of the hole transport layer may be in a range of about 50 Å to about 2,000 Å, e.g., about 100 Å to about 1,500 Å. When the thicknesses of the hole transport region, the hole injection layer, and the hole transport layer are within these ranges, satisfactory hole transporting characteristics may be obtained without a substantial increase in driving voltage.

The emission auxiliary layer may help increase light emission efficiency by compensating for an optical resonance distance according to the wavelength of light emitted by an emission layer, and the electron blocking layer may block the flow of electrons from an electron transport region. The emission auxiliary layer and the electron blocking layer may include the materials as described above.

[p-dopant]

The hole transport region may further include, in addition to these materials, a charge-generation material for the improvement of conductive properties. The charge-generation material may be homogeneously or non-homogeneously dispersed in the hole transport region.

The charge-generation material may be, e.g., a p-dopant.

In an implementation, a lowest unoccupied molecular orbital (LUMO) of the p-dopant may be -3.5 eV or less.

In an implementation, the p-dopant may include at least one selected from a quinone derivative, a metal oxide, and a cyano group-containing compound.

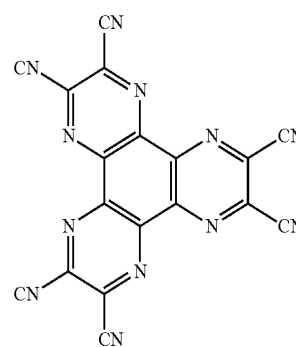
For example, the p-dopant may include at least one selected from:

a quinone derivative, such as tetracyanoquinodimethane (TCNQ) and 2,3,5,6-tetrafluoro-7,7,8,8-tetracyanoquinodimethane (F4-TCNQ);

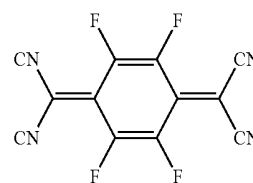
a metal oxide, such as tungsten oxide or molybdenum oxide;

1,4,5,8,9,11-hexaazatriphenylene-hexacarbonitrile (HAT-CN); and

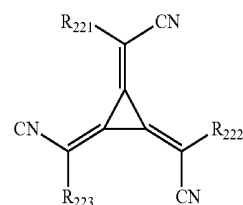
a compound represented by Formula 221:



<HAT-CN>



<F4-TCNQ>



<Formula 221>

In Formula 221,

R₂₂₁ to R₂₂₃ may each independently be selected from a substituted or unsubstituted C₃-C₁₀ cycloalkyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkyl group, a substituted or unsubstituted C₃-C₁₀ cycloalkenyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkenyl group, a substituted or unsubstituted C₆-C₆₀ aryl group, a substituted or unsubstituted C₁-C₆₀ heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted

monovalent non-aromatic condensed heteropolycyclic group, wherein at least one from R₂₂₁ to R₂₂₃ may include at least one substituent selected from a cyano group, —F, —Cl, —Br, —I, a C₁-C₂₀ alkyl group substituted with —F, a C₁-C₂₀ alkyl group substituted with —Cl, a C₁-C₂₀ alkyl group substituted with —Br, and a C₁-C₂₀ alkyl group substituted with —I.

[Emission Layer in Organic Layer 150]

When the organic light-emitting device 10 is a full color organic light-emitting device, the emission layer may be patterned into a red emission layer, a green emission layer, or a blue emission layer, according to a sub-pixel. In an implementation, the emission layer may have a stacked structure of two or more layers selected from a red emission layer, a green emission layer, and a blue emission layer, in which the two or more layers contact each other or are separated from each other. In an implementation, the emission layer may include two or more materials selected from a red light-emitting material, a green light-emitting material, and a blue light-emitting material, in which the two or more materials are mixed with each other in a single layer to emit white light.

The emission layer may include a host and a dopant. The dopant may include at least one selected from a phosphorescent dopant and a fluorescent dopant.

In an implementation, an amount of the dopant in the emission layer may be, e.g., in a range of about 0.01 parts to about 15 parts by weight based on 100 parts by weight of the host.

In an implementation, a thickness of the emission layer may be in a range of about 100 Å to about 1,000 Å, e.g., about 200 Å to about 600 Å. When the thickness of the emission layer is within this range, excellent light-emission characteristics may be obtained without a substantial increase in driving voltage.

[Host in Emission Layer]

In one or more embodiments, the host may include a compound represented by Formula 301 below.



In Formula 301,

Ar₃₀₁ may be a substituted or unsubstituted C₅-C₆₀ carbocyclic group or a substituted or unsubstituted C₁-C₆₀ heterocyclic group,

xb11 may be 1, 2, or 3,

L₃₀₁ may be selected from a substituted or unsubstituted C₃-C₁₀ cycloalkylene group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkylene group, a substituted or unsubstituted C₃-C₁₀ cycloalkenylene group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkenylene group, a substituted or unsubstituted C₆-C₆₀ arylene group, a substituted or unsubstituted C₁-C₆₀ heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group.

xb1 may be an integer of 0 to 5,

R₃₀₁ may be selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a substituted or unsubstituted C₁-C₆₀ alkyl group, a substituted or unsubstituted C₂-C₆₀ alkenyl group, a substituted or unsubstituted C₂-C₆₀ alkynyl group, a substituted or unsubstituted C₁-C₆₀ alkoxy group, a substituted or unsubstituted C₃-C₁₀ cycloalkyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkyl group, a substituted or unsubstituted C₃-C₁₀ cycloalkenyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkenyl group, a substituted or unsubstituted C₆-C₆₀ aryl group, a substituted or unsubstituted C₆-C₆₀ aryloxy group, a substituted or unsubstituted C₆-C₆₀ arylthio group, a substituted or unsubstituted C₁-C₆₀ heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —Si(Q₃₀₁)(Q₃₀₂)(Q₃₀₃), —N(Q₃₀₁)(Q₃₀₂), —B(Q₃₀₁)(Q₃₀₂), —C(=O)(Q₃₀₁), —S(=O)₂(Q₃₀₁), and —P(=O)(Q₃₀₁)(Q₃₀₂), and

xb21 may be an integer of 1 to 5,

wherein Q₃₀₁ to Q₃₀₃ may each independently be selected from a C₁-C₁₀ alkyl group, a C₁-C₁₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

In one or more embodiments, Ar₃₀₁ in Formula 301 may be selected from:

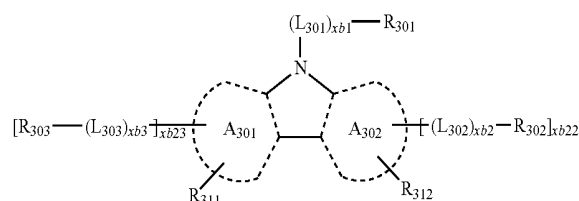
a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, a dibenzofuran group and a dibenzothiophene group; and

a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, a dibenzofuran group, and a dibenzothiophene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group. —Si(Q₃₁)(Q₃₂)(Q₃₃), —N(Q₃₁)(Q₃₂), —B(Q₃₁)(Q₃₂), —C(=O)(Q₃₁), —S(=O)₂(Q₃₁), and —P(=O)(Q₃₁)(Q₃₂);

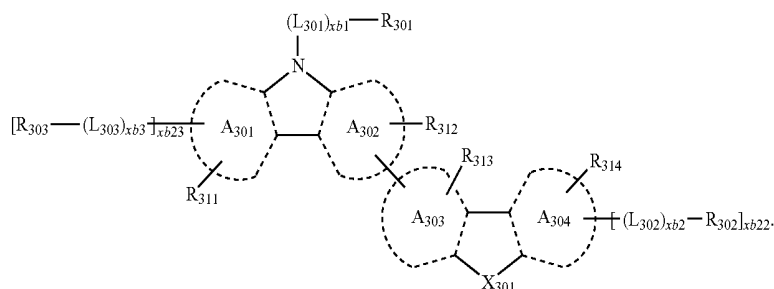
wherein Q₃₁ to Q₃₃ may each independently be selected from a C₁-C₁₀ alkyl group, a C₁-C₁₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

When xb11 in Formula 301 is two or more, two or more Ar₃₀₁(s) may be linked via a single bond.

In one or more embodiments, the compound represented by Formula 301 may be represented by Formula 301-1 or 301-2:



-continued



<Formula 301-2>

In Formulae 301-1 and 301-2,

A_{301} to A_{304} may each independently be selected from a benzene group, a naphthalene group, a phenanthrene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a pyridine group, a pyrimidine group, an indene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, an indole group, a carbazole group, a benzocarbazole group, a dibenzocarbazole group, a furan group, a benzofuran group, a dibenzofuran group, a naphthofuran group, a benzonaphthofuran group, a dinaphthofuran group, a thiophene group, a benzothiophene group, a dibenzothiophene group, naphthothiophene group, benzonaphthothiophene group, and dinaphthothiophene group.

X_{301} may be O, S, or N-[(L_{304}) $_{xb4}$ - R_{304}],

R_{311} to R_{314} may each independently be selected from hydrogen, deuterium, -F, -Cl, -Br, -I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group -Si(Q_{31})(Q_{32})(Q_{33}), -N(Q_{31})(Q_{32}), -B(Q_{31})(Q_{32}), -C(=O)(Q_{31}), -S(=O)₂(Q_{31}), and -P(=O)(Q_{31})(Q_{32}),

$xb22$ and $xb23$ may each independently be 0, 1, or 2,

L_{301} , $xb1$, R_{301} , and Q_{31} to Q_{33} may be the same as described above,

L_{302} to L_{304} may each independently be the same as described in connection with L_{301} ,

$xb2$ to $xb4$ may each independently be the same as described in connection with $xb1$, and

R_{302} to R_{304} may each independently be the same as described in connection with R_{301} .

For example, L_{301} to L_{304} in Formulae 301, 301-1, and 301-2 may each independently be selected from:

a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylylene group, a fluoranthenylylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylylene group, a hexacenylylene group, a pentacenylylene group, a thiophenylylene group, a furanylylene group, a carbazolylylene group, an indolylylene group, an isoindolylylene group, a benzofuranylylene group, a benzothiophenylylene group, a dibenzofuranylylene group, a dibenzothiophenylylene group, a benzocarbazolylylene group, a dibenzocarbazolylylene group, a dibenzosilolylylene group, a pyridinylylene group, an imidazolylylene group, a pyrazolylylene group, a thiazolylylene group, an isothiazolylylene group, an oxazolylylene group, an isoxazolylylene group, a thiadiazolylylene group, an oxadiazolylylene group, a pyrazinylylene group, a pyrimidinylylene group, a pyridazinylylene group, a triazinylylene group, a quinolinylene

group, an isoquinolinylene group, a benzoquinolinylene group, a phthalazinylene group, a naphthyridinylene group, a quinoxalinylene group, a quinazolinylene group, a cinnolinylene group, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a phenazinylene group, a benzimidazolylylene group, an isobenzothiazolylylene group, a benzoxazolylylene group, an isobenzoxazolylylene group, a triazolylylene group, a tetrazolylylene group, an imidazopyridinylene group, an imidazopyrimidinylene group, and an azacarbazolylylene group; and

a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylylene group, a phenanthrenylene group, an anthracenylylene group, a fluoranthenylylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylylene group, a hexacenylylene group, a pentacenylylene group, a thiophenylylene group, a furanylylene group, a carbazolylylene group, an indolylylene group, an isoindolylylene group, a benzofuranylylene group, a benzothiophenylylene group, a dibenzofuranylylene group, a dibenzothiophenylylene group, a benzocarbazolylylene group, a dibenzocarbazolylylene group, a dibenzosilolylylene group, a pyridinylylene group, an imidazolylylene group, a pyrazolylylene group, a thiazolylylene group, an isothiazolylylene group, an oxazolylylene group, an isoxazolylylene group, a thiadiazolylylene group, an oxadiazolylylene group, a pyrazinylylene group, a pyrimidinylylene group, a pyridazinylylene group, a triazinylylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a phthalazinylene group, a naphthyridinylene group, a quinoxalinylene group, a quinazolinylene group, a cinnolinylene group, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a phenazinylene group, a benzimidazolylylene group, an isobenzothiazolylylene group, a benzoxazolylylene group, an isobenzoxazolylylene group, a triazolylylene group, a tetrazolylylene group, an imidazopyridinylene group, an imidazopyrimidinylene group, and an azacarbazolylylene group, each substituted with at least one selected from deuterium, -F, -Cl, -Br, -I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocar-

bazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an aza carbazolyl group, $-\text{Si}(\text{Q}_{31})(\text{Q}_{32})(\text{Q}_{33})$, $-\text{N}(\text{Q}_{31})(\text{Q}_{32})$, $-\text{B}(\text{Q}_{31})(\text{Q}_{32})$, $-\text{C}(=\text{O})(\text{Q}_{31})$, $-\text{S}(=\text{O})_2(\text{Q}_{31})$, and $-\text{P}(=\text{O})(\text{Q}_{31})(\text{Q}_{32})$,

wherein Q_{31} to Q_{33} are the same as described above.

In one or more embodiments, R_{301} to R_{304} in Formulae 301, 301-1, and 301-2 may each independently be selected from:

a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group; and

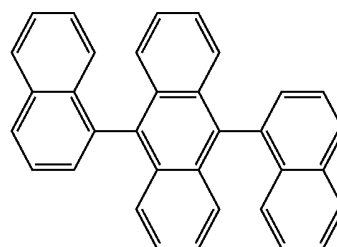
a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl

group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group, each substituted with at least one selected from deuterium, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an aza carbazolyl group, $-\text{Si}(\text{Q}_{31})(\text{Q}_{32})(\text{Q}_{33})$, $-\text{N}(\text{Q}_{31})(\text{Q}_{32})$, $-\text{B}(\text{Q}_{31})(\text{Q}_{32})$, $-\text{C}(=\text{O})(\text{Q}_{31})$, $-\text{S}(=\text{O})_2(\text{Q}_{31})$, and $-\text{P}(=\text{O})(\text{Q}_{31})(\text{Q}_{32})$,

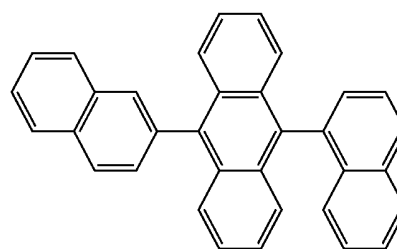
wherein Q_{31} to Q_{33} are the same as described above.

In one or more embodiments, the host may include an alkaline-earth metal complex. For example, the host may be selected from a Be complex (for example, Compound H55), a Mg complex, and a Zn complex.

The host may include at least one selected from 9,10-di(2-naphthyl)anthracene (ADN), 2-methyl-9,10-bis(naphthalen-2-yl)anthracene (MADN), 9,10-di-(2-naphthyl)-2-t-butyl-anthracene (TBADN), a 4,4'-bis(N-carbazolyl)-1,1'-biphenyl (CBP), 1,3-di-9-carbazolylbenzene (mCP), 1,3,5-tri(carbazol-9-yl)benzene (TCP), and Compounds H1 to H55:



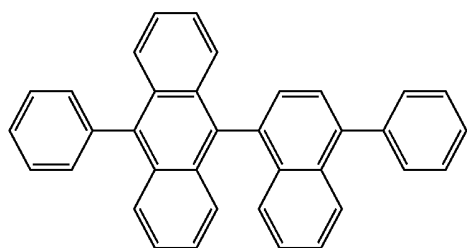
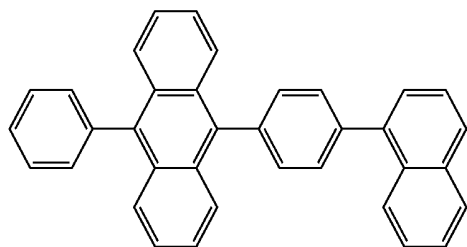
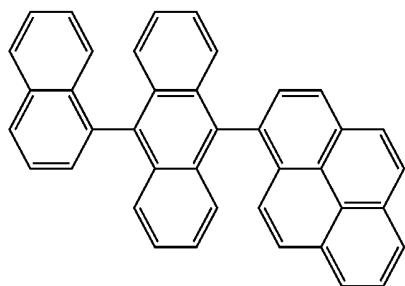
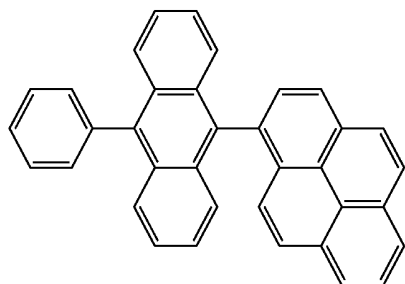
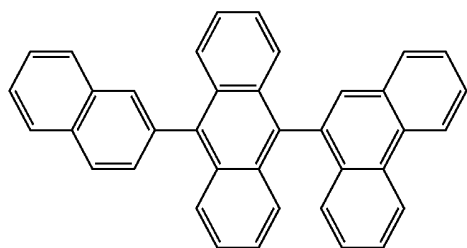
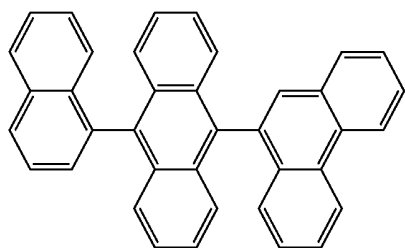
H1



H2

77

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78

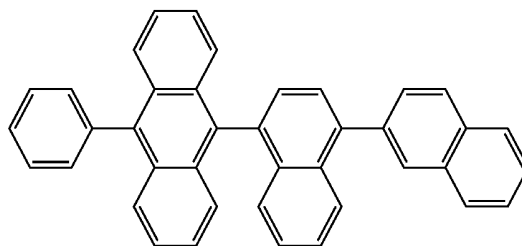
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H3

H9

5

10



H4

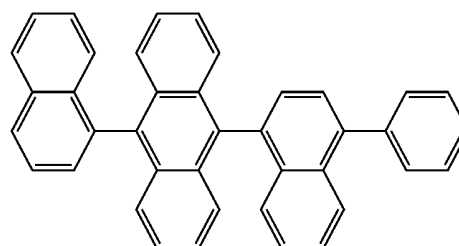
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H10

20

H5

25



30

H11

35

H6

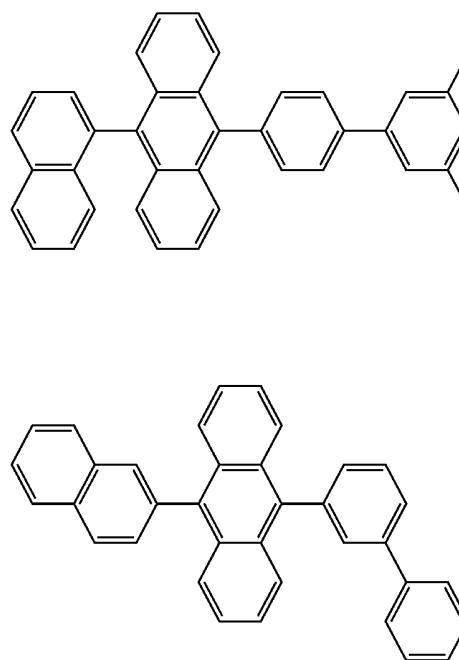
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H12

45

H7

50



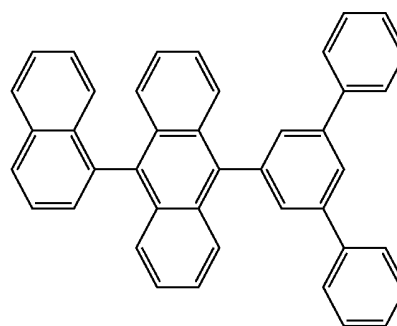
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H13

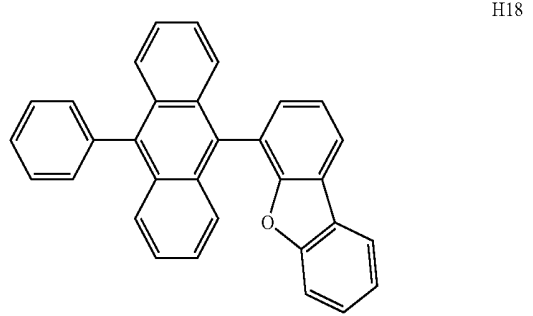
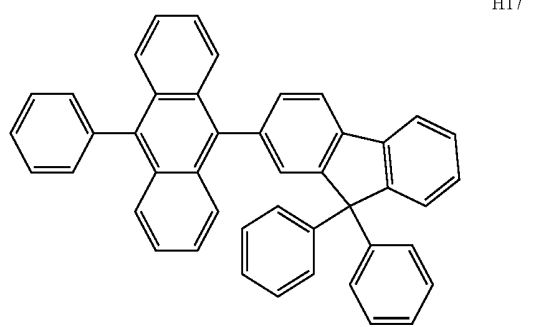
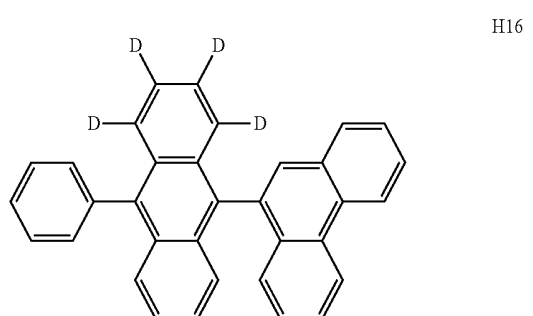
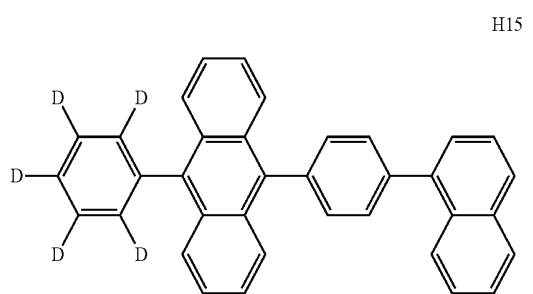
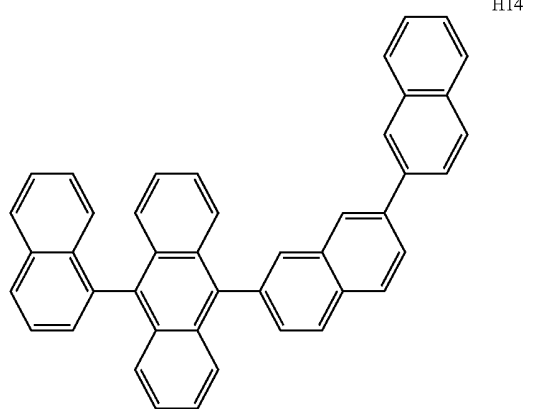
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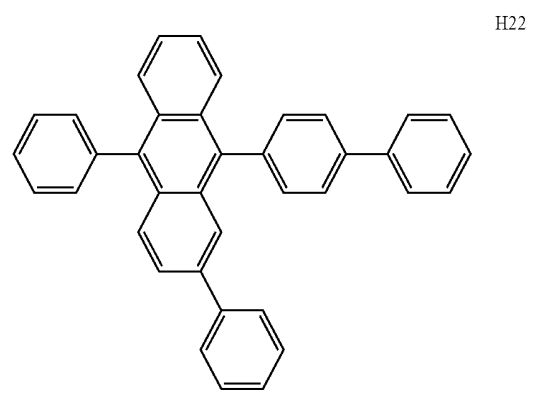
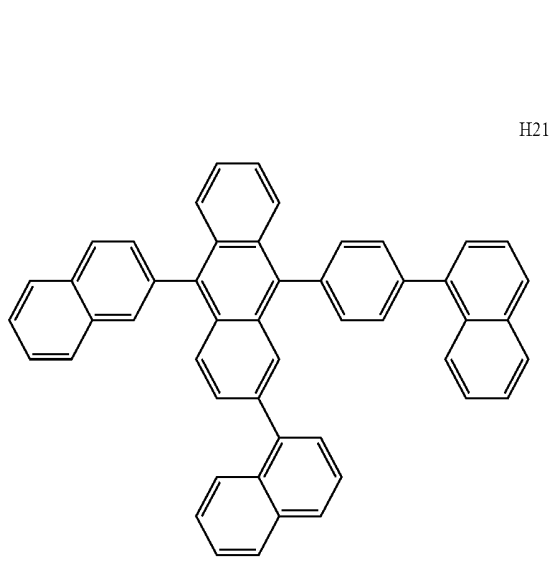
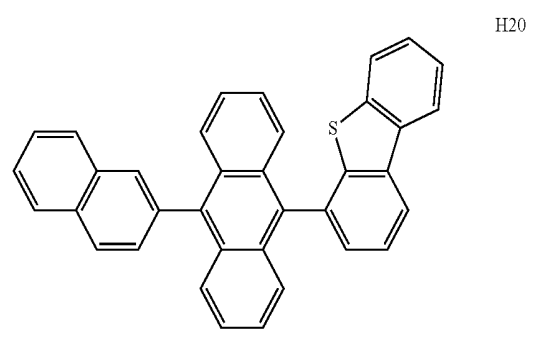
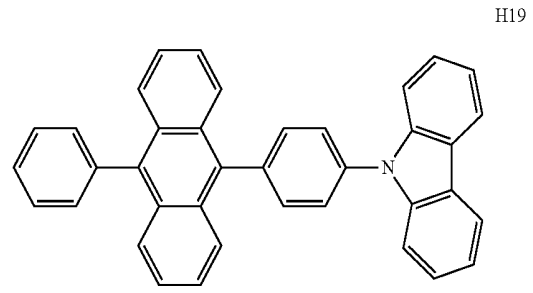
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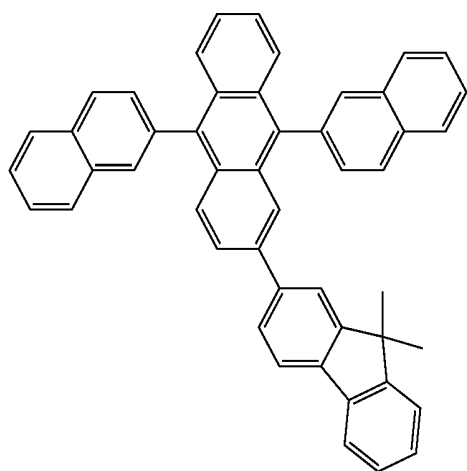


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H23

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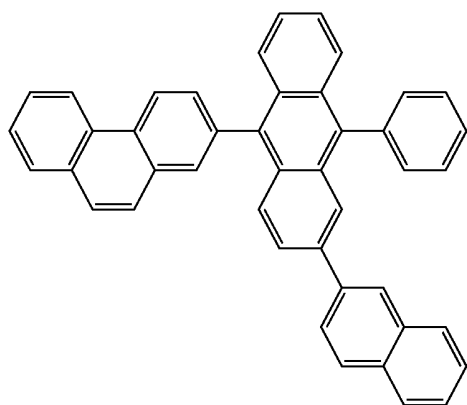
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H24

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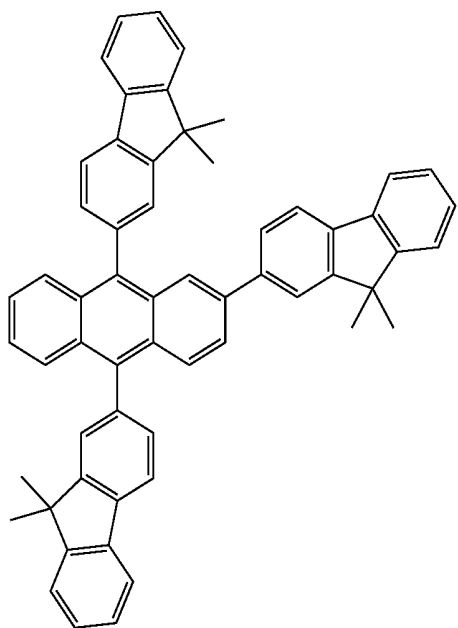
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H25

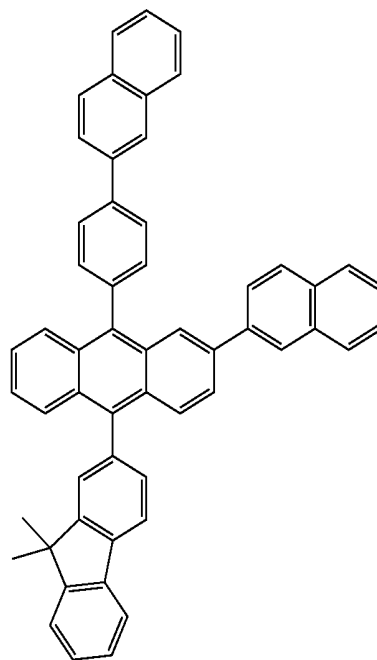
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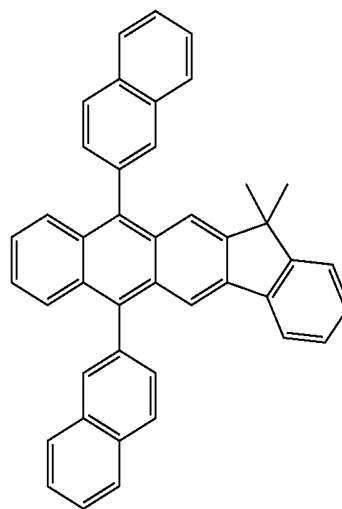
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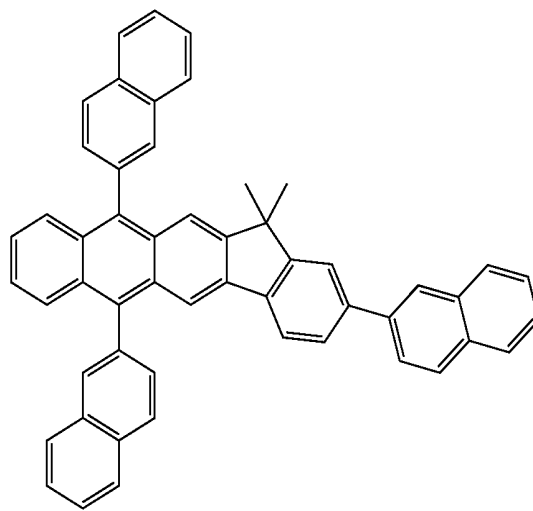
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H27



H28



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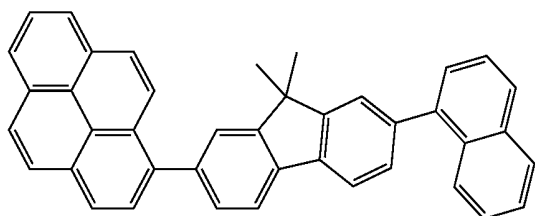
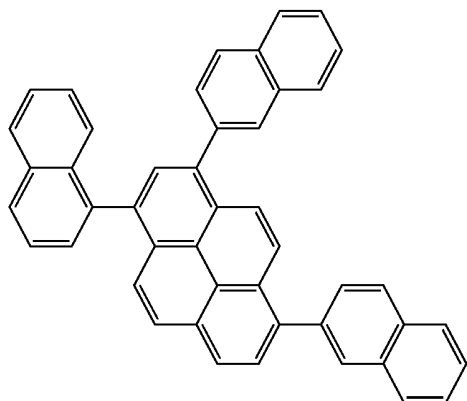
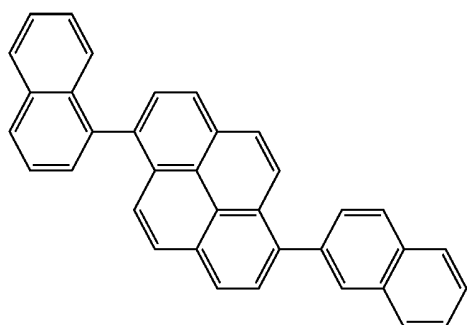
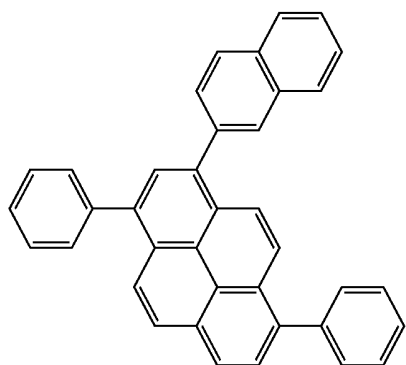
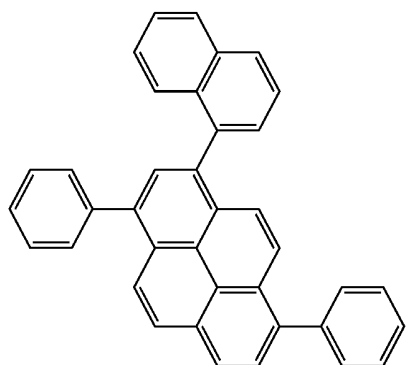
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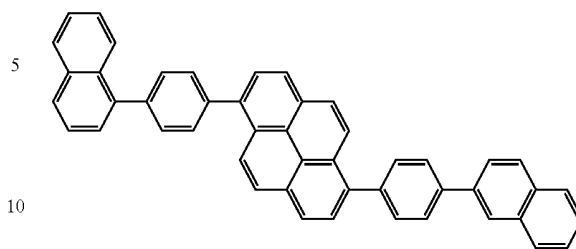


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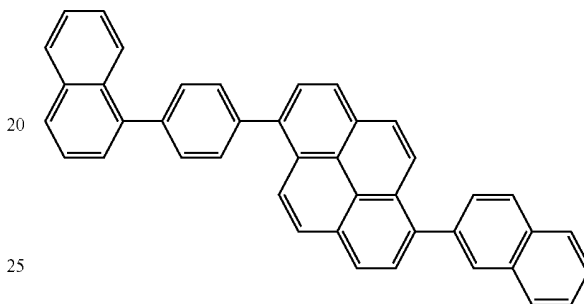
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H34



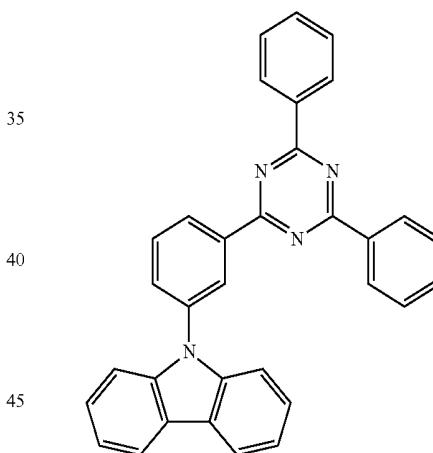
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H35



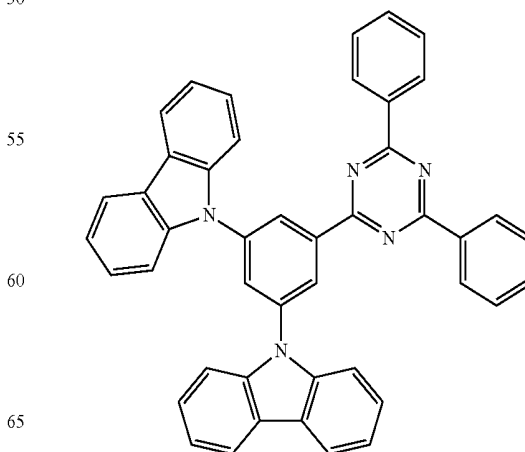
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H36



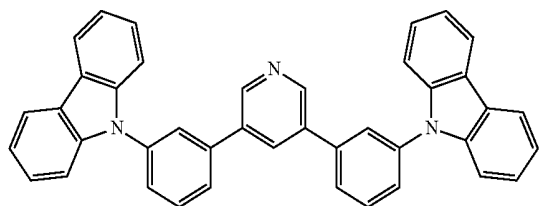
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H37



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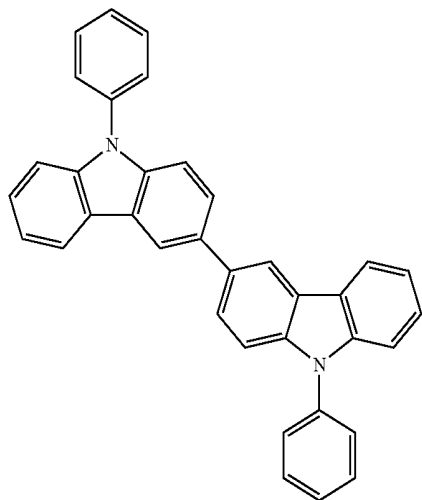
H38



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H39



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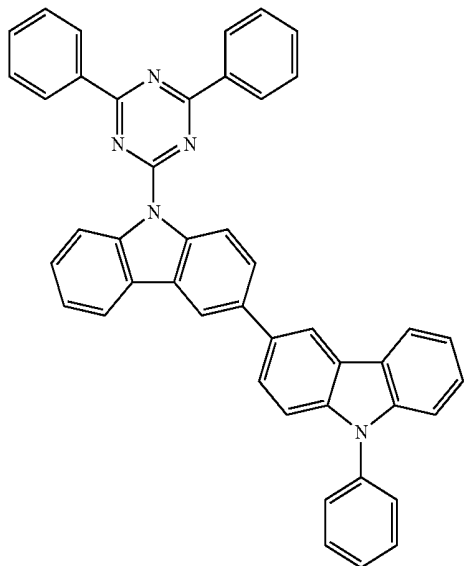
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H40



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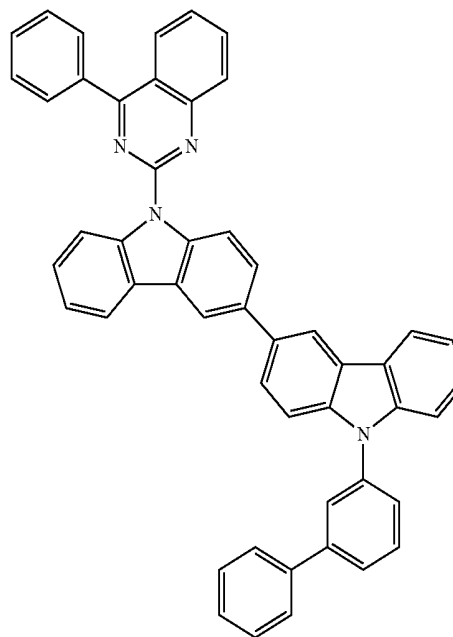
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86

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H41



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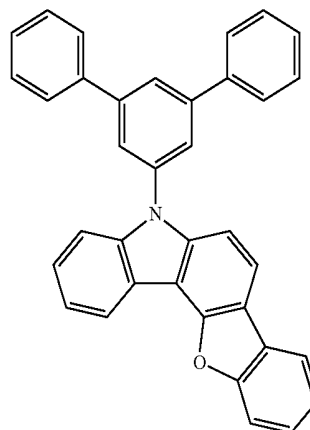
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H42



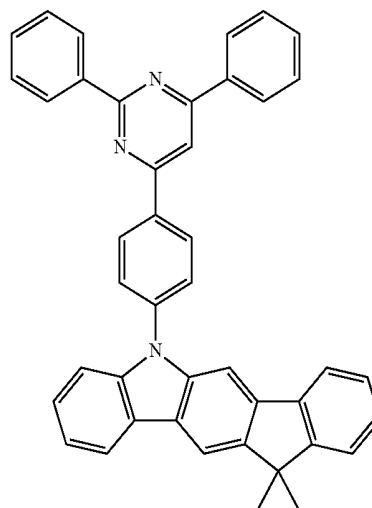
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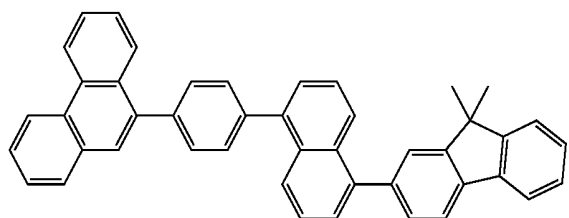
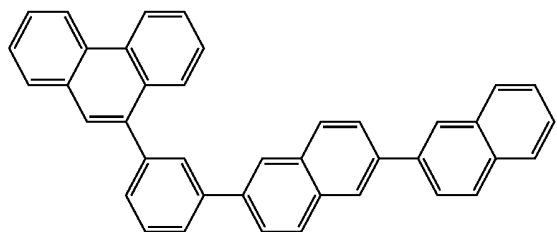
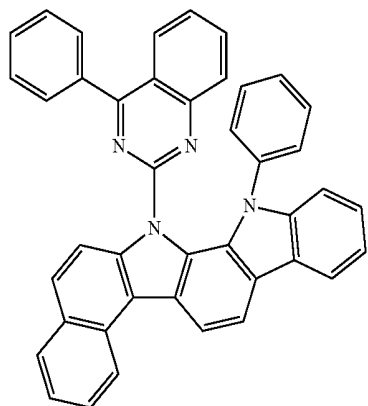
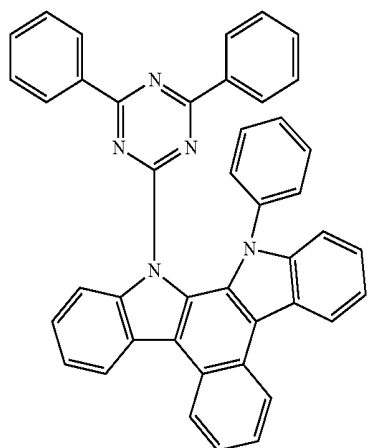
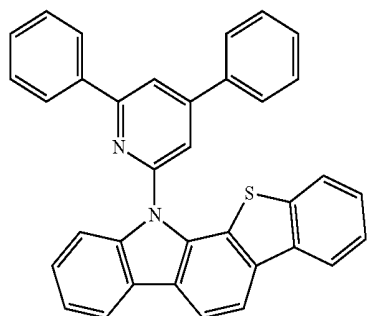
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H43



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88

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H44

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H46

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H47

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H48

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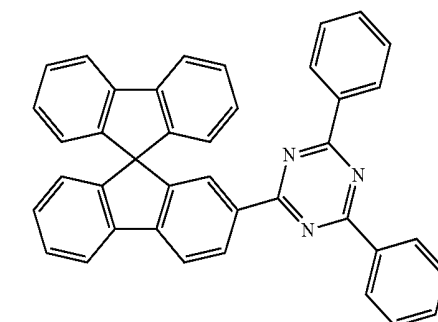
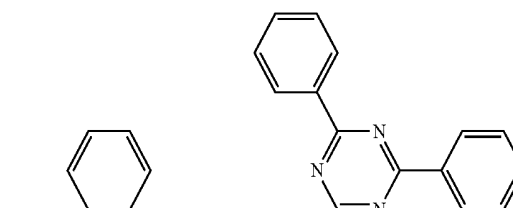
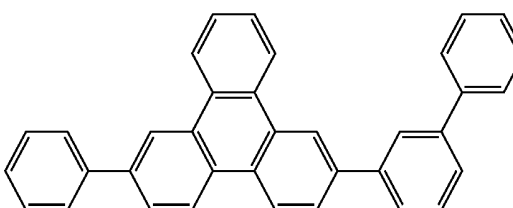
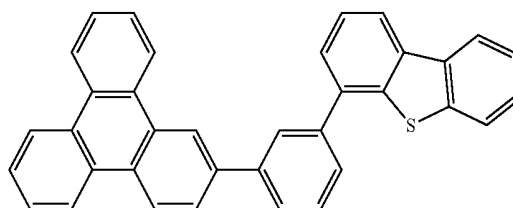
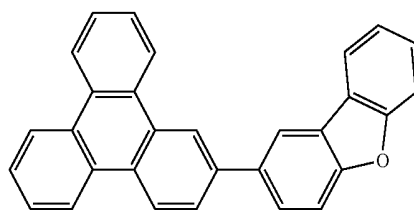
H49

H50

H51

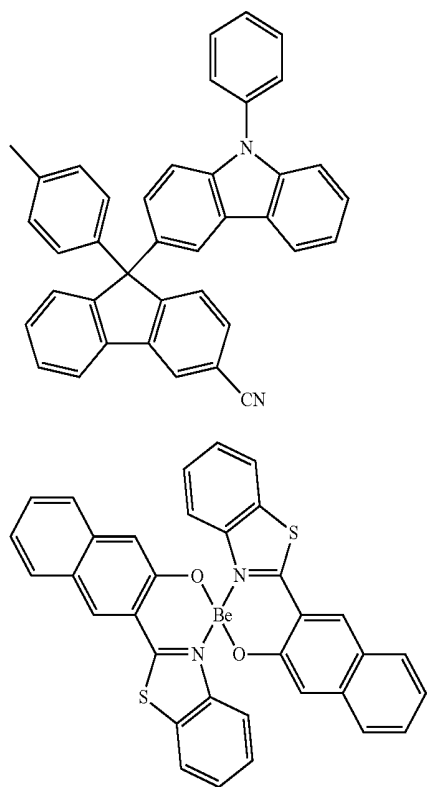
H52

H53



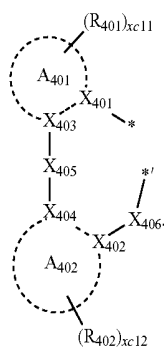
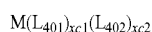
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[Phosphorescent Dopant Included in Emission Layer in Organic Layer 150]

The phosphorescent dopant may include an organometallic complex represented by Formula 401 below:



In Formulae 401 and 402,

M may be selected from iridium (Ir), platinum (Pt), palladium (Pd), osmium (Os), titanium (Ti), zirconium (Zr), hafnium (Hf), europium (Eu), terbium (Tb), rhodium (Rh), and thulium (Tm),

L_{401} may be selected from ligands represented by Formula 402, and $xc1$ may be 1, 2, or 3, wherein when $xc1$ is two or more, two or more $L_{401}(s)$ may be identical to or different from each other,

L_{402} may be an organic ligand, and $xc2$ may be an integer of 0 to 4, wherein when $xc2$ is two or more, two or more $L_{402}(s)$ may be identical to or different from each other,

X_{401} to X_{404} may each independently be nitrogen or carbon,

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H54 X_{401} and X_{403} may be linked via a single bond or a double bond, and X_{402} and X_{404} may be linked via a single bond or a double bond,

5 A_{401} and A_{402} may each independently be selected from a C_5 - C_{60} carbocyclic group or a C_1 - C_{60} heterocyclic group,

X_{405} may be a single bond, $*-O-*'$, $*-S-*'$, $*-C(=O)-*'$, $*-N(Q_{411})-*'$, $*-C(Q_{411})(Q_{412})-*'$, $*-C(Q_{411})=C(Q_{412})-*'$, $*-C(Q_{411})=*'$, or $*=C(Q_{411})=*'$,
10 wherein Q_{411} and Q_{412} may be hydrogen, deuterium, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, or a naphthyl group,

X_{406} may be a single bond, O, or S,

15 R_{401} and R_{402} may each independently be selected from hydrogen, deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a substituted or unsubstituted C_1 - C_{20} alkyl group, a substituted or unsubstituted

H55 C_1 - C_{20} alkoxy group, a substituted or unsubstituted C_3 - C_{10} cycloalkyl group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkyl group, a substituted or unsubstituted

20 C_3 - C_{10} cycloalkenyl group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkenyl group, a substituted or unsubstituted

25 C_6 - C_{60} aryl group, a substituted or unsubstituted C_6 - C_{60} aryloxy group, a substituted or unsubstituted C_6 - C_{60} arylthio group, a substituted or unsubstituted C_1 - C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group and a substituted

30 or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, $-Si(Q_{401})(Q_{402})(Q_{403})$, $-N(Q_{401})(Q_{402})$, $-B(Q_{401})(Q_{402})$, $-C(=O)(Q_{401})$, $-S(=O)_2(Q_{401})$, and $-P(=O)(Q_{401})(Q_{402})$, wherein Q_{401} to Q_{403}

35 may each independently be selected from a C_1 - C_{10} alkyl group, a C_1 - C_{10} alkoxy group, a C_6 - C_{20} aryl group, and a C_1 - C_{20} heteroaryl group,

40 $xc11$ and $xc12$ may each independently be an integer of 0 to 10, and

* and *' in Formula 402 each indicate a binding site to M in Formula 401.

In one or more embodiments, A_{401} and A_{402} in Formula

45 402 may each independently be selected from a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, an indene group, a pyrrole group, a thiophene group, a furan group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, a quinoline group, an isoquinoline group, a benzoquinoline group, a quinoxaline group, a quinazoline group, a carbazole group, a benzimidazole group, a benzofuran group, a benzothio-

45 402 may each independently be selected from a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, an indene group, a pyrrole group, a thiophene group, a furan group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, a quinoline group, an isoquinoline group, a benzoquinoline group, a quinoxaline group, a quinazoline group, a carbazole group, a benzimidazole group, a benzofuran group, a benzothio-

45 402 may each independently be selected from a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, an indene group, a pyrrole group, a thiophene group, a furan group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, a quinoline group, an isoquinoline group, a benzoquinoline group, a quinoxaline group, a quinazoline group, a carbazole group, a benzimidazole group, a benzofuran group, a benzothio-

45 402 may each independently be selected from a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, an indene group, a pyrrole group, a thiophene group, a furan group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, a quinoline group, an isoquinoline group, a benzoquinoline group, a quinoxaline group, a quinazoline group, a carbazole group, a benzimidazole group, a benzofuran group, a benzothio-

45 402 may each independently be selected from a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, an indene group, a pyrrole group, a thiophene group, a furan group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, a quinoline group, an isoquinoline group, a benzoquinoline group, a quinoxaline group, a quinazoline group, a carbazole group, a benzimidazole group, a benzofuran group, a benzothio-

45 402 may each independently be selected from a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, an indene group, a pyrrole group, a thiophene group, a furan group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, a quinoline group, an isoquinoline group, a benzoquinoline group, a quinoxaline group, a quinazoline group, a carbazole group, a benzimidazole group, a benzofuran group, a benzothio-

45 402 may each independently be selected from a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, an indene group, a pyrrole group, a thiophene group, a furan group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, a quinoline group, an isoquinoline group, a benzoquinoline group, a quinoxaline group, a quinazoline group, a carbazole group, a benzimidazole group, a benzofuran group, a benzothio-

45 402 may each independently be selected from a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, an indene group, a pyrrole group, a thiophene group, a furan group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, a quinoline group, an isoquinoline group, a benzoquinoline group, a quinoxaline group, a quinazoline group, a carbazole group, a benzimidazole group, a benzofuran group, a benzothio-

45 402 may each independently be selected from a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, an indene group, a pyrrole group, a thiophene group, a furan group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, a quinoline group, an isoquinoline group, a benzoquinoline group, a quinoxaline group, a quinazoline group, a carbazole group, a benzimidazole group, a benzofuran group, a benzothio-

45 402 may each independently be selected from a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, an indene group, a pyrrole group, a thiophene group, a furan group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, a quinoline group, an isoquinoline group, a benzoquinoline group, a quinoxaline group, a quinazoline group, a carbazole group, a benzimidazole group, a benzofuran group, a benzothio-

45 402 may each independently be selected from a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, an indene group, a pyrrole group, a thiophene group, a furan group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, a quinoline group, an isoquinoline group, a benzoquinoline group, a quinoxaline group, a quinazoline group, a carbazole group, a benzimidazole group, a benzofuran group, a benzothio-

45 402 may each independently be selected from a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, an indene group, a pyrrole group, a thiophene group, a furan group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, a quinoline group, an isoquinoline group, a benzoquinoline group, a quinoxaline group, a quinazoline group, a carbazole group, a benzimidazole group, a benzofuran group, a benzothio-

45 402 may each independently be selected from a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, an indene group, a pyrrole group, a thiophene group, a furan group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, a quinoline group, an isoquinoline group, a benzoquinoline group, a quinoxaline group, a quinazoline group, a carbazole group, a benzimidazole group, a benzofuran group, a benzothio-

91

a C₁-C₂₀ alkyl group and a C₁-C₂₀ alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a phenyl group, a naphthyl group, a cyclopentyl group, a cyclohexyl group, an adamantanyl group, a norbornanyl group, and a norbornenyl group;

a cyclopentyl group, a cyclohexyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group;

a cyclopentyl group, a cyclohexyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a cyclopentyl group, a cyclohexyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group; and

—Si(Q₄₀₁)(Q₄₀₂)(Q₄₀₃), —N(Q₄₀₁)(Q₄₀₂), —B(Q₄₀₁)(Q₄₀₂), —C(=O)(Q₄₀₁), —S(=O)₂(Q₄₀₁) and —P(=O)(Q₄₀₁)(Q₄₀₂),

wherein Q₄₀₁ to Q₄₀₃ may each independently be selected from a C₁-C₁₀ alkyl group, a C₁-C₁₀ alkoxy group, a phenyl group, a biphenyl group, and a naphthyl group.

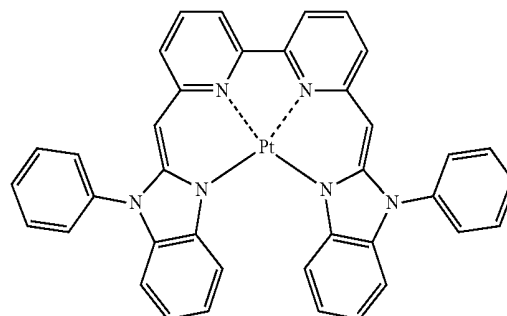
In one or more embodiments, when xc1 in Formula 401 is two or more, two A₄₀₁(s) in two or more L₄₀₁(s) may optionally be linked to each other via X₄₀₇, which is a linking group, or two A₄₀₂(s) in two or more L₄₀₁(s) may optionally be linked to each other via X₄₀₈, which is a linking group (see Compounds PD1 to PD4 and PD7). X₄₀₇ and X₄₀₈ may each independently be a single bond, *—O—*, *—S—*, *—C(=O)—*, *—N(Q₄₁₃)—*, *—C(Q₄₁₃)(Q₄₁₄)—*, or *—C(Q₄₁₃)=C(Q₄₁₄)—* (wherein Q₄₁₃ and Q₄₁₄ may each independently be hydrogen, deuterium, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, or a naphthyl group).

L₄₀₂ in Formula 401 may be a monovalent, divalent, or trivalent organic ligand. For example, L₄₀₂ may be selected from a halogen, a diketone (for example, acetylacetonate), a carboxylic acid (for example, picolinate), —C(=O), an isonitrile, —CN, and a phosphorus-containing compound (for example, phosphine, or phosphite).

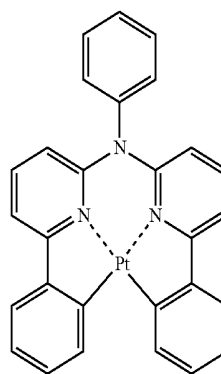
In one or more embodiments, the phosphorescent dopant may be selected from, for example, Compounds PD1 to PD25:

92

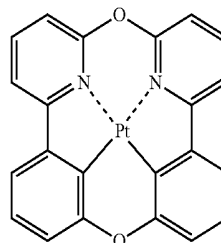
PD1



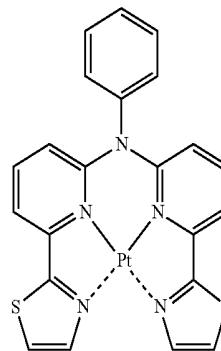
PD2



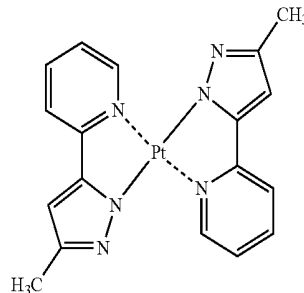
PD3



PD4

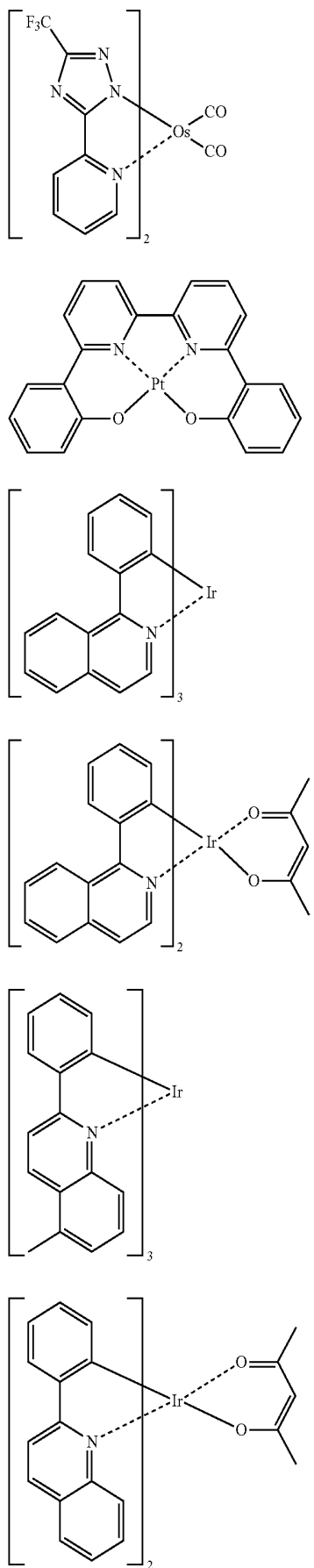


PD5



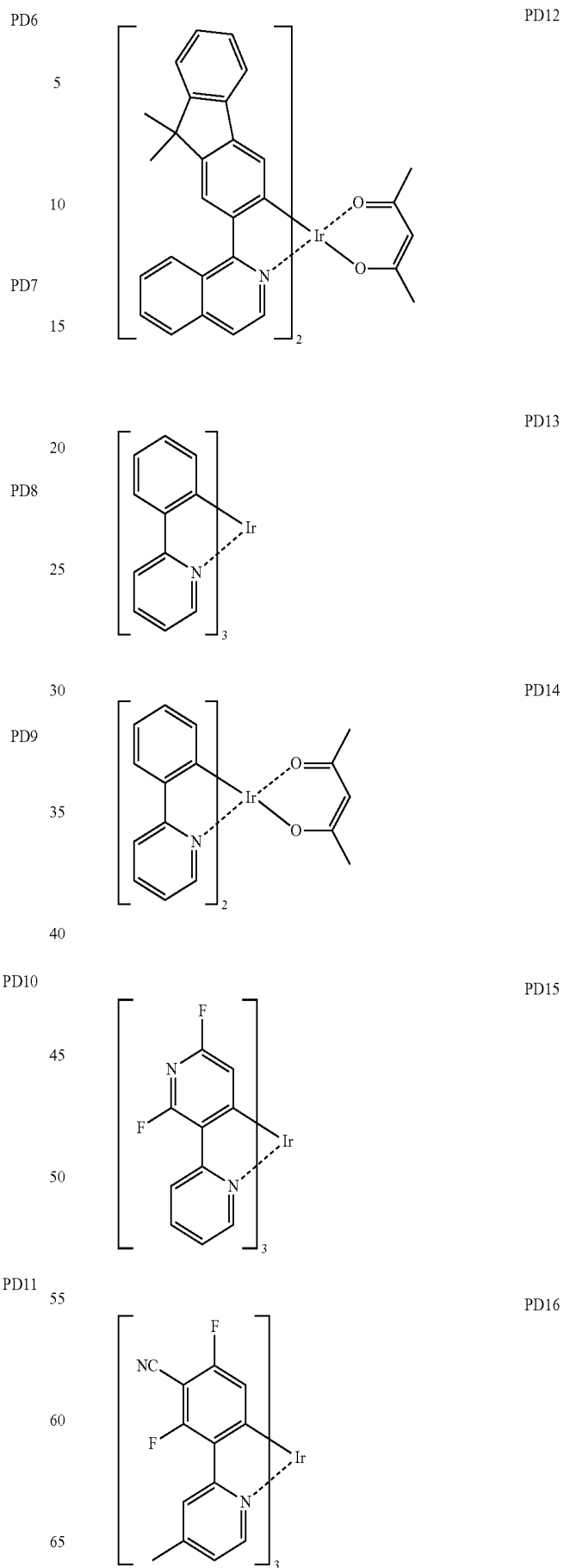
93

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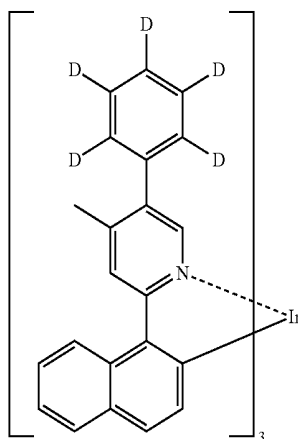
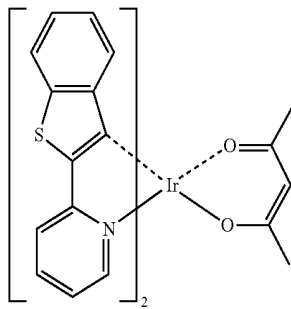
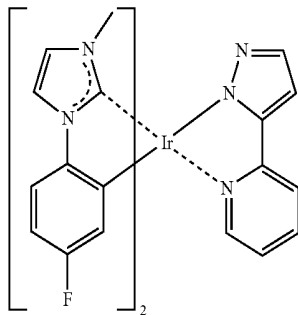
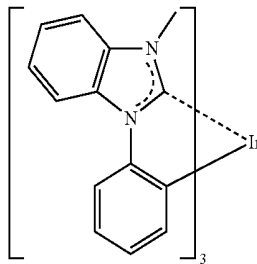
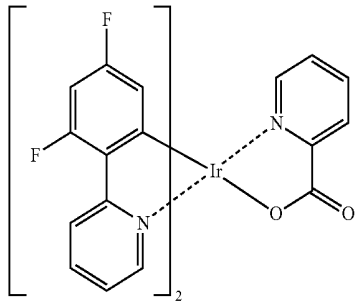


94

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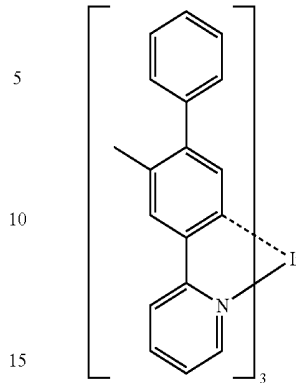


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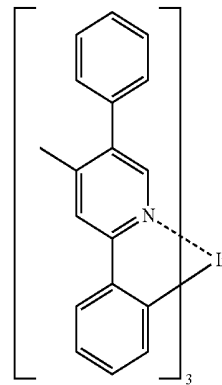


96
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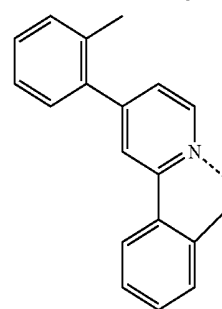
PD17



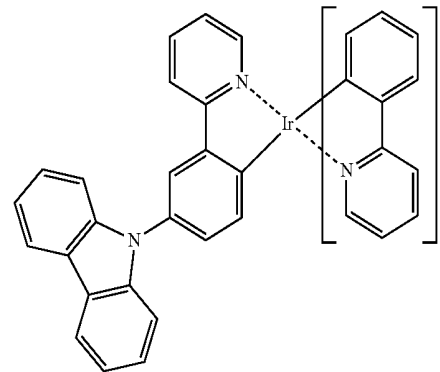
PD18 15



PD19 25



PD20 40

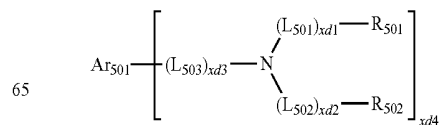


PD21 50

[Fluorescent Dopant in Emission Layer]

The fluorescent dopant may include an arylamine compound or a styrylamine compound.

The fluorescent dopant may include a compound represented by Formula 501 below.



<Formula 501>

PD22

PD23

PD24

PD25

In Formula 501,

Ar₅₀₁ may be a substituted or unsubstituted C₅-C₆₀ carbocyclic group or a substituted or unsubstituted C₁-C₆₀ heterocyclic group,

L₅₀₁ to L₅₀₃ may each independently be selected from a substituted or unsubstituted C₃-C₁₀ cycloalkylene group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkylene group, a substituted or unsubstituted C₃-C₁₀ cycloalkenylene group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkenylene group, a substituted or unsubstituted C₆-C₆₀ arylylene group, a substituted or unsubstituted C₁-C₆₀ heteroarylylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group,

xd1 to xd3 may each independently be an integer of 0 to 3,

R₅₀₁ and R₅₀₂ may each independently be selected from a substituted or unsubstituted C₃-C₁₀ cycloalkyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkyl group, a substituted or unsubstituted C₃-C₁₀ cycloalkenyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkenyl group, a substituted or unsubstituted C₆-C₆₀ aryl group, a substituted or unsubstituted C₆-C₆₀ aryloxy group, a substituted or unsubstituted C₆-C₆₀ arylthio group, a substituted or unsubstituted C₁-C₆₀ heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, and

xd4 may be an integer of 1 to 6.

In one or more embodiments, Ar₅₀₁ in Formula 501 may be selected from:

a naphthalene group, a heptalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, and an indenophenanthrene group; and

a naphthalene group, a heptalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, and an indenophenanthrene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

In one or more embodiments, L₅₀₁ to L₅₀₃ in Formula 501 may each independently be selected from:

a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylylene group, a fluoranthenylylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylylene group, a hexacenylylene group, a pentacenylylene group, a thiophenylylene group, a furanylylene group, a carbazolylylene group, an indolylylene group, an isoindolylylene group, a benzofuranylylene group, a benzothiophenylylene group, a dibenzofuranylylene group, a dibenzothiophenylylene group, a benzocarbazolylylene group, a dibenzocarbazolylylene group, a dibenzosilolylylene group, and a pyridinylylene group; and

a phenylene group, a naphthylene group, a fluorenylylene group, a spiro-bifluorenylylene group, a benzofluorenylylene group, a dibenzofluorenylylene group, a phenanthrenylene group, an anthracenylylene group, a fluoranthenylylene group, a

triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylylene group, a hexacenylylene group, a pentacenylylene group, a thiophenylylene group, a furanylylene group, a carbazolylylene group, an indolylylene group, an isoindolylylene group, a benzofuranylylene group, a benzothiophenylylene group, a dibenzofuranylylene group, a dibenzothiophenylylene group, a benzocarbazolylylene group, a dibenzocarbazolylylene group, a dibenzosilolylylene group, and a pyridinylylene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenylyl group, a pentacenylyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, and a pyridinyl group.

In one or more embodiments, R₅₀₁ and R₅₀₁ in Formula 502 may each independently be selected from:

a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenylyl group, a pentacenylyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, and a pyridinyl group; and

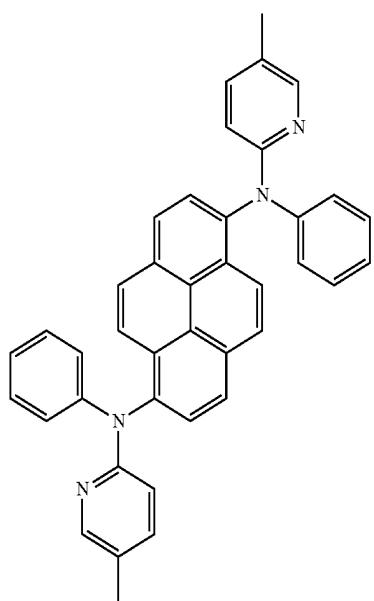
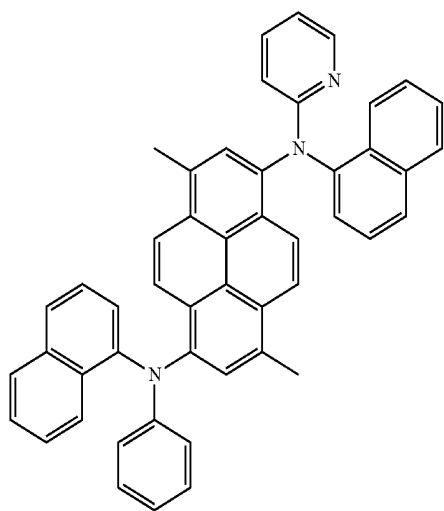
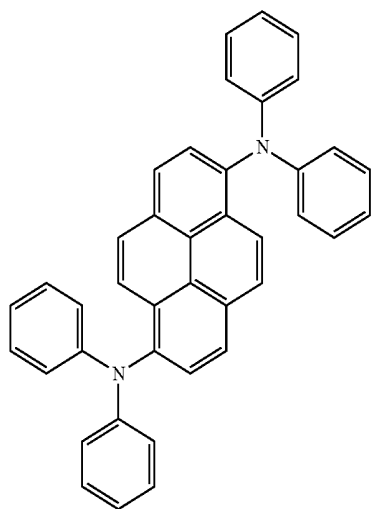
a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenylyl group, a pentacenylyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, and a pyridinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenylyl group, a pentacenylyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, and —Si(Q₃₁)(Q₃₂)(Q₃₃),

wherein Q₃₁ to Q₃₃ may each be selected from a C₁-C₁₀ alkyl group, a C₁-C₁₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

In one or more embodiments, xd4 in Formula 501 may be 2.

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For example, the fluorescent dopant may be selected from Compounds FD1 to FD22:

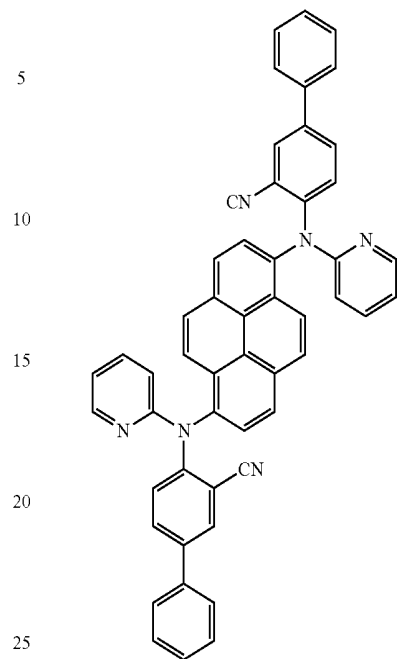


100

-continued

FD4

FD1 5

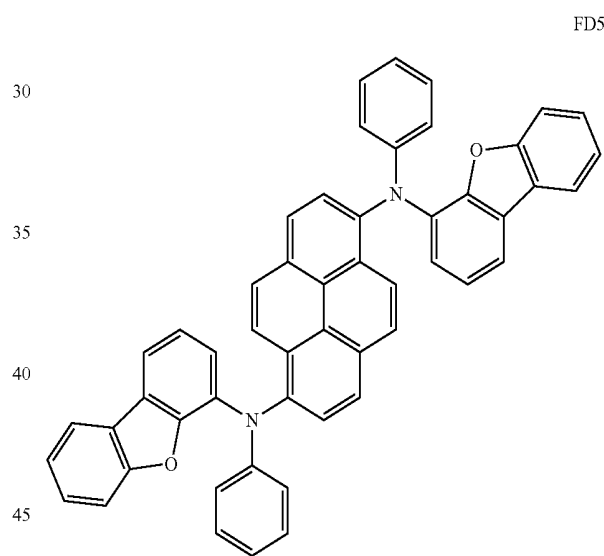


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FD2 25



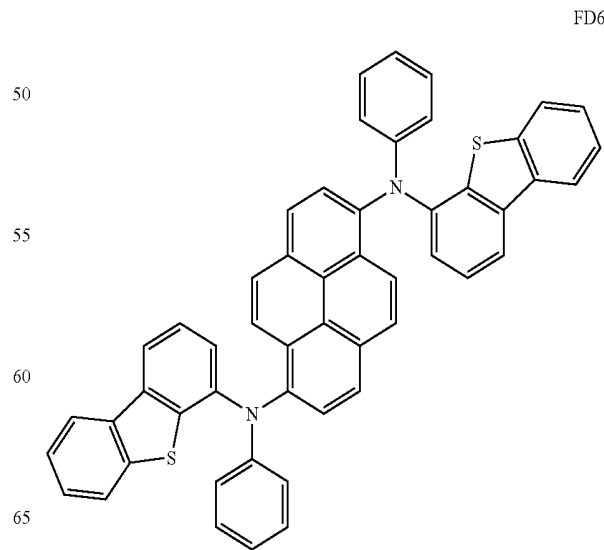
FD5

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FD3 45



FD6

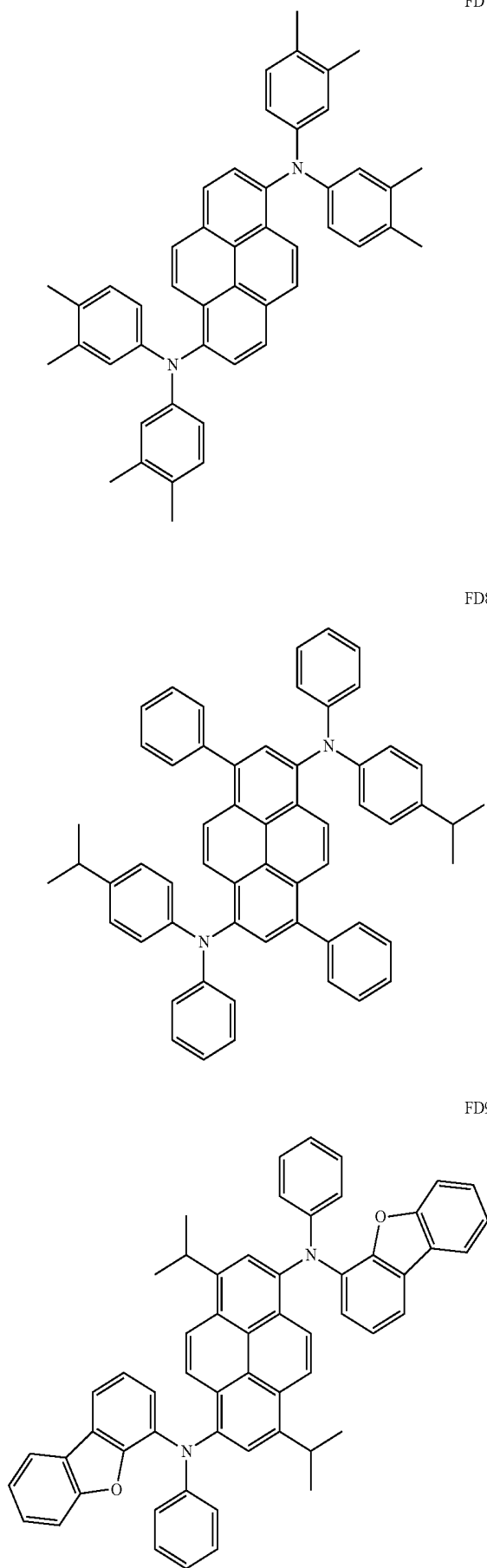
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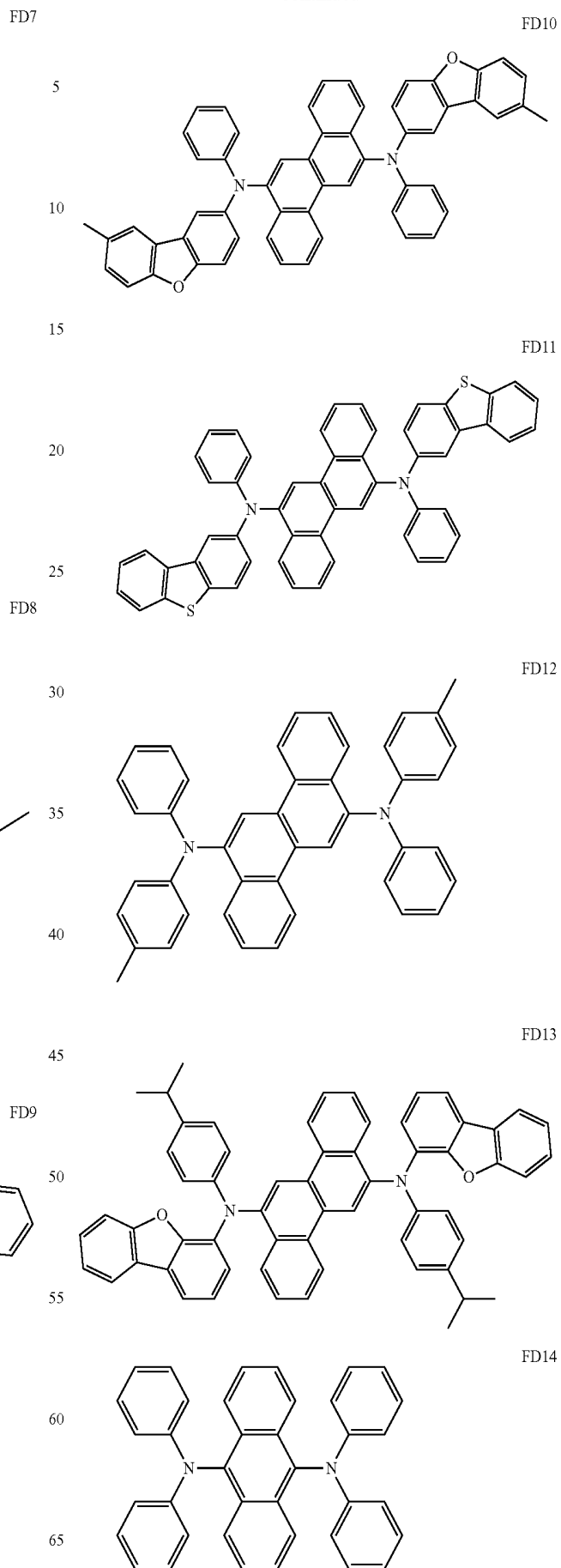
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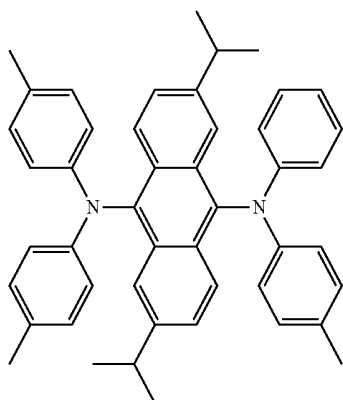
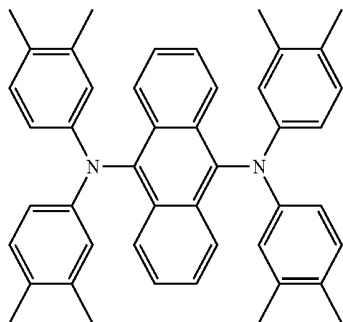
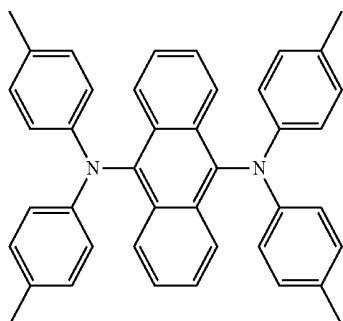
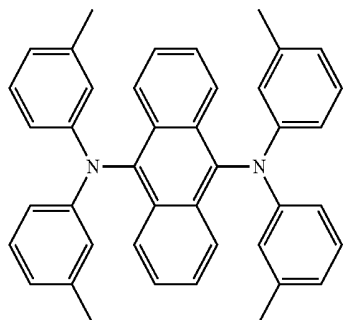
101
-continued



102
-continued



103
-continued



104
-continued

FD15

FD19

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FD16

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FD17

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FD20

FD21

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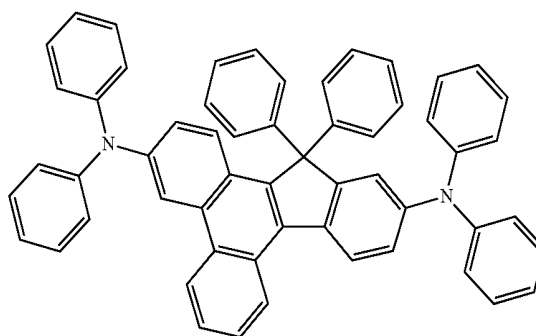
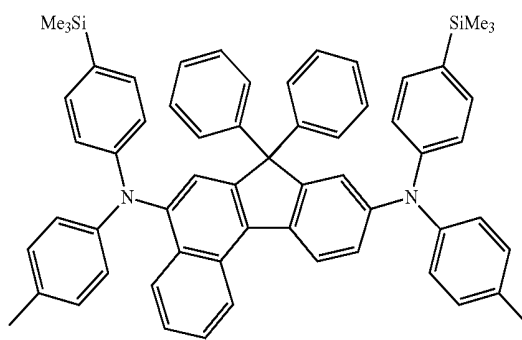
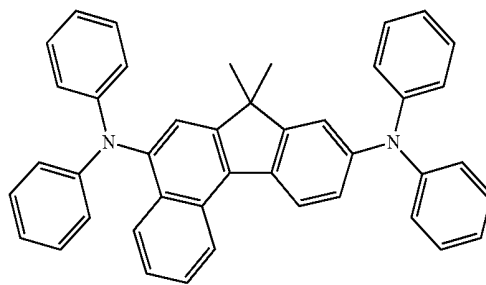
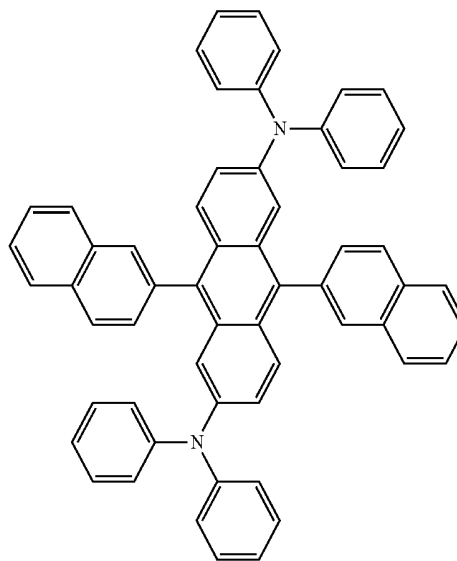
FD22

FD18

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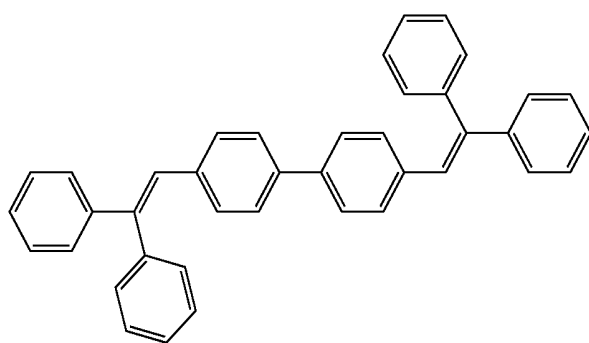
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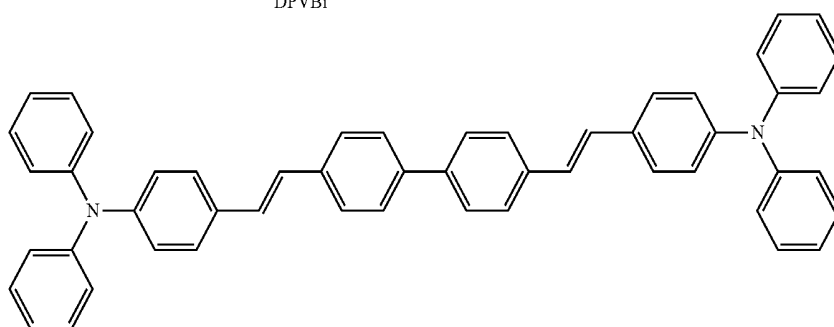
In one or more embodiments, the fluorescent dopant may be selected from the following compounds.

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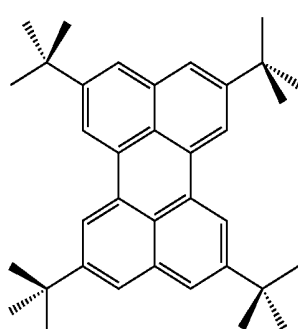
106



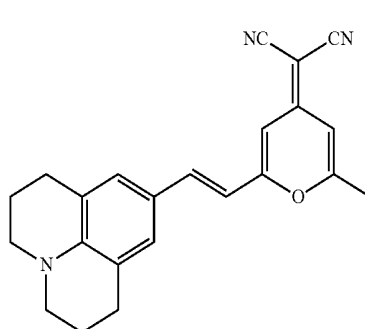
DPVBi



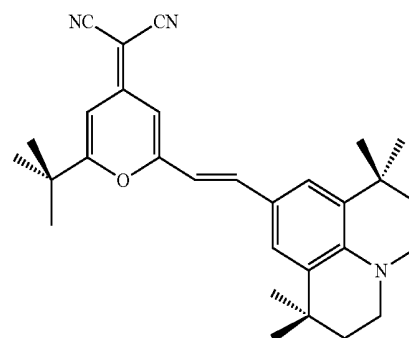
DPAVBi



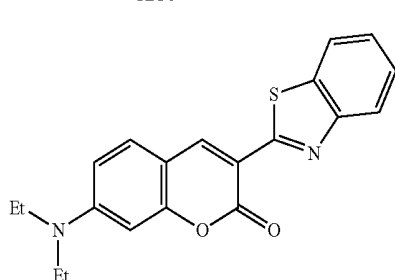
TBPe



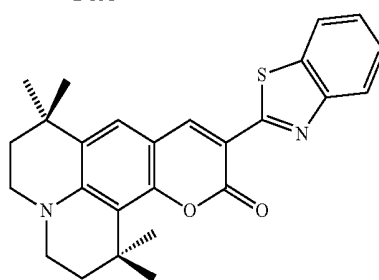
DCM



DCJTb



Coumarin 6



C545T

[Electron Transport Region in Organic Layer 150]

The electron transport region may have i) a single-layered structure including a single layer including a single material, ii) a single-layered structure including a single layer including a plurality of different materials, or iii) a multi-layered structure having a plurality of layers including a plurality of different materials.

The electron transport region may include at least one selected from a buffer layer, a hole blocking layer, an electron control layer, an electron transport layer, and an electron injection layer.

For example, the electron transport region may have an electron transport layer/electron injection layer structure, a

55 hole blocking layer/electron transport layer/electron injection layer structure, an electron control layer/electron transport layer/electron injection layer structure, or a buffer layer/electron transport layer/electron injection layer structure, wherein for each structure, constituting layers are sequentially stacked from an emission layer.

60 The electron transport region (e.g., a buffer layer, a hole blocking layer, an electron control layer, or an electron transport layer in the electron transport region) may include a metal-free compound containing at least one π electron-depleted nitrogen-containing ring.

65 The " π electron-depleted nitrogen-containing ring" indicates a C_1 - C_{60} heterocyclic group having at least one $*-N=*$ moiety as a ring-forming moiety.

For example, the “ π electron-depleted nitrogen-containing ring” may be i) a 5-membered to 7-membered heteromonocyclic group having at least one $*-N=*$ moiety, ii) a heteropolycyclic group in which two or more 5-membered to 7-membered heteromonocyclic groups each having at least one $*-N=*$ moiety are condensed with each other, or iii) a heteropolycyclic group in which at least one of 5-membered to 7-membered heteromonocyclic groups, each having at least one $*-N=*$ moiety, is condensed with at least one C_5-C_{60} carbocyclic group.

Examples of the π electron-depleted nitrogen-containing ring may include an imidazole, a pyrazole, a thiazole, an isothiazole, an oxazole, an isoxazole, a pyridine, a pyrazine, a pyrimidine, a pyridazine, an indazole, a purine, a quinoline, an isoquinoline, a benzoquinoline, a phthalazine, a naphthyridine, a quinoxaline, a quinazoline, a cinnoline, a phenanthridine, an acridine, a phenanthroline, a phenazine, a benzimidazole, an isobenzothiazole, a benzoxazole, an isobenzoxazole, a triazole, a tetrazole, an oxadiazole, a triazine, thiadiazol, an imidazopyridine, an imidazopyrimidine, and an azacarbazole.

For example, the electron transport region may include a compound represented by Formula 601:



In Formula 601,

Ar_{601} may be a substituted or unsubstituted C_5-C_{60} carbocyclic group or a substituted or unsubstituted C_1-C_{60} heterocyclic group,

$xe11$ may be 1, 2, or 3,

L_{601} may be selected from a substituted or unsubstituted C_3-C_{10} cycloalkylene group, a substituted or unsubstituted C_1-C_{10} heterocycloalkylene group, a substituted or unsubstituted C_3-C_{10} cycloalkenylene group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenylene group, a substituted or unsubstituted C_6-C_{60} arylene group, a substituted or unsubstituted C_1-C_{60} heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group;

$xe1$ may be an integer of 0 to 5,

R_{601} may be selected from a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, a substituted or unsubstituted C_1-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, $-Si(Q_{601})(Q_{602})(Q_{603})$, $-C(=O)(Q_{601})$, $-S(=O)_2(Q_{601})$, and $-P(=O)(Q_{601})(Q_{602})$.

Q_{601} to Q_{603} may each independently be a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, or a naphthyl group, and

$xe21$ may be an integer of 1 to 5.

In one or more embodiments, at least one of $Ar_{601}(s)$ in the number of $xe11$ and/or at least one of $R_{601}(s)$ in the number of $xe21$ may include the π electron-depleted nitrogen-containing ring.

In one or more embodiments, ring Ar_{601} in Formula 601 may be selected from:

a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an

anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, a dibenzofuran group, a dibenzothiophene group, a carbazole group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, an indazole group, a purine group, a quinoline group, an isoquinoline group, a benzoquinoline group, a phthalazine group, naphthyridine group, a quinoxaline group, a quinazoline group, a cinnoline group, a phenanthridine group, an acridine group, a phenanthroline group, a phenazine group, a benzimidazole group, an iso-benzothiazole group, a benzoxazole group, an isobenzoxazole group, a triazole group, a tetrazole group, an oxadiazole group, a triazine group, thiadiazol group, an imidazopyridine group, an imidazopyrimidine group, and an azacarbazole group; and

a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, a dibenzofuran group, a dibenzothiophene group, a carbazole group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, an indazole group, a purine group, a quinoline group, an isoquinoline group, a benzoquinoline group, a phthalazine group, naphthyridine group, a quinoxaline group, a quinazoline group, a cinnoline group, a phenanthridine group, an acridine group, a phenanthroline group, a phenazine group, a benzimidazole group, an iso-benzothiazole group, a benzoxazole group, an isobenzoxazole group, a triazole group, a tetrazole group, an oxadiazole group, a triazine group, thiadiazol group, an imidazopyridine group, an imidazopyrimidine group, and an azacarbazole group, each substituted with at least one selected from deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, $-Si(Q_{31})(Q_{32})(Q_{33})$, $-S(=O)_2(Q_{31})$, and $-P(=O)(Q_{31})(Q_{32})$,

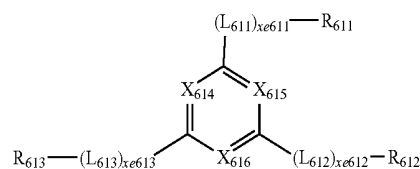
wherein Q_{31} to Q_{33} may each independently be selected from a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

When $xe11$ in Formula 601 is two or more, two or more $Ar_{601}(s)$ may be linked to each other via a single bond.

In one or more embodiments, Ar_{601} in Formula 601 may be an anthracene group.

In one or more embodiments, a compound represented by Formula 601 may be represented by Formula 601-1:

<Formula 601-1>



In Formula 601-1,

X_{614} may be N or C(R_{614}), X_{615} may be N or C(R_{615}), X_{616} may be N or C(R_{616}), and at least one selected from X_{614} to X_{616} may be N,

L_{611} to L_{613} may each independently be substantially the same as described in connection with L_{601} ,

xe611 to xe613 may each independently be substantially the same as described in connection with xe1,

R_{611} to R_{613} may each independently be substantially the same as described in connection with R_{601} ,

R_{614} to R_{616} may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

In one or more embodiments, L_{601} and L_{611} to L_{613} in Formulae 601 and 601-1 may each independently be selected from:

a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylenylene group, a hexacenylenylene group, a pentacenylenylene group, a thiophenylenylene group, a furanylenylene group, a carbazolylenylene group, an indolylenylene group, an isoindolylenylene group, a benzofuranylenylene group, a benzothiophenylenylene group, a dibenzofuranylenylene group, a dibenzothiophenylenylene group, a benzocarbazolylenylene group, a dibenzocarbazolylenylene group, a dibenzosilolylenylene group, a pyridinylenylene group, an imidazolylenylene group, a pyrazolylenylene group, a thiazolylenylene group, an isothiazolylenylene group, an oxazolylenylene group, an isoxazolylenylene group, a thiadiazolylenylene group, an oxadiazolylenylene group, a pyrazinylenylene group, a pyrimidinylenylene group, a pyridazinylenylene group, a triazininylenylene group, a quinolininylenylene group, a pyridazininylenylene group, a triazininylenylene group, a quinolininylenylene group, a phthalazininylenylene group, a naphthyridinylenylene group, a quinoxalinylenylene group, a quinazolinylenylene group, a cinnolininylenylene group, a phenanthridinylenylene group, an acridinylenylene group, a phenanthrolinylenylene group, a phenazininylenylene group, a benzimidazolylenylene group, an isobenzothiazolylenylene group, a benzoxazolylenylene group, an isobenzoxazolylenylene group, a triazolinylenylene group, a tetrazolylenylene group, an imidazopyridinylenylene group, an imidazopyrimidinylenylene group, and an azacarbazolylenylene group; and

a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylenylene group, a hexacenylenylene group, a pentacenylenylene group, a thiophenylenylene group, a furanylenylene group, a carbazolylenylene group, an indolylenylene group, an isoindolylenylene group, a benzofuranylenylene group, a benzothiophenylenylene group, a dibenzofuranylenylene group, a dibenzothiophenylenylene group, a benzocarbazolylenylene group, a dibenzocarbazolylenylene group, a dibenzosilolylenylene group, a pyridinylenylene group, an imidazolylenylene group, a pyrazolylenylene group, a thiazolylenylene group,

an isothiazolylenylene group, an oxazolylenylene group, an isoxazolylenylene group, a thiadiazolylenylene group, an oxadiazolylenylene group, a pyrazinylenylene group, a pyrimidinylenylene group, a pyridazininylenylene group, a triazininylenylene group, a quinolininylenylene group, an isoquinolininylenylene group, a benzoquinolininylenylene group, a phthalazininylenylene group, a naphthyridinylenylene group, a quinoxalinylenylene group, a quinazolinylenylene group, a cinnolininylenylene group, a phenanthridinylenylene group, an acridinylenylene group, a phenanthrolinylenylene group, a phenazininylenylene group, a benzimidazolylenylene group, an isobenzothiazolylenylene group, a benzoxazolylenylene group, an isobenzoxazolylenylene group, a triazolinylenylene group, a tetrazolylenylene group, an imidazopyridinylenylene group, an imidazopyrimidinylenylene group, and an azacarbazolylenylene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenylyl group, a pentacenylyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinylyl group, a quinazolinylyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group.

In one or more embodiments, xe1 and xe611 to xe613 in Formulae 601 and 601-1 may each independently be 0, 1, or 2.

In one or more embodiments, R_{601} and R_{611} to R_{613} in Formulae 601 and 601-1 may each independently be selected from:

a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenylyl group, a pentacenylyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadi-

111

azolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group;

a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group; and

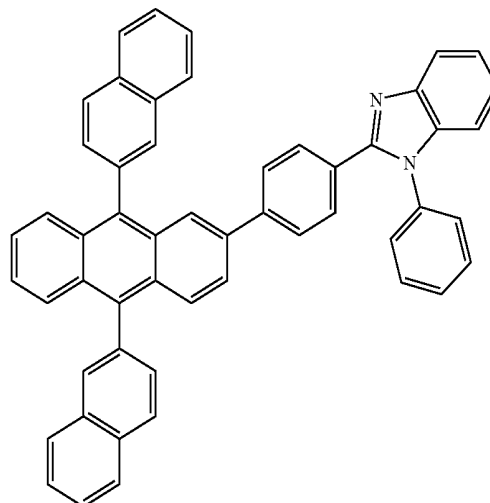
—S(=O)₂(Q₆₀₁) and —P(=O)(Q₆₀₁)(Q₆₀₂),

wherein Q₆₀₀ and Q₆₀₂ are substantially the same as described above.

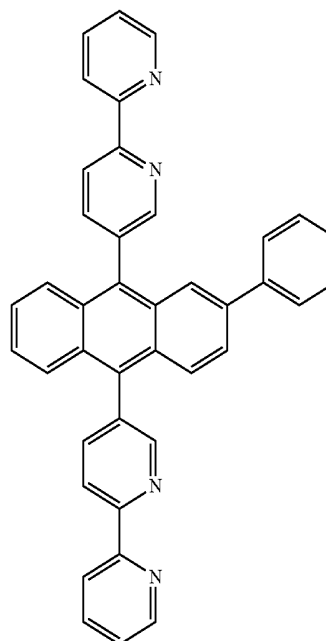
112

The electron transport region may include at least one compound selected from Compounds ET1 to ET36:

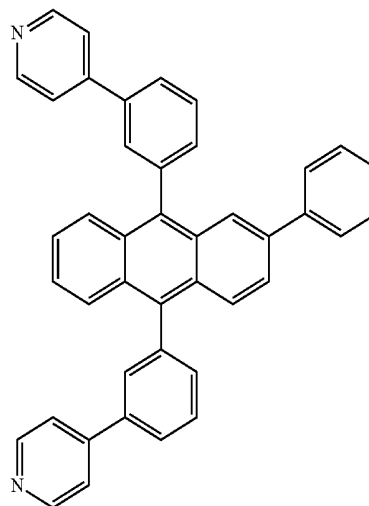
ET1



ET2

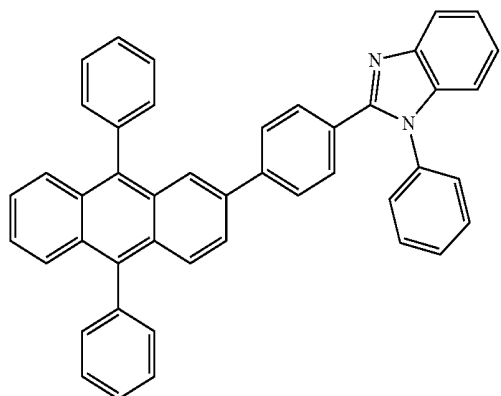


ET3



113
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ET4



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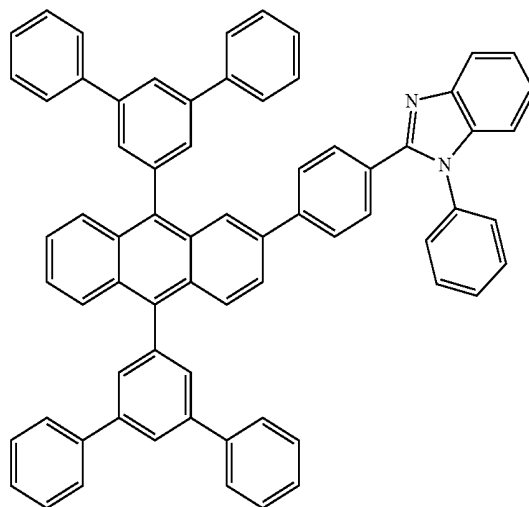
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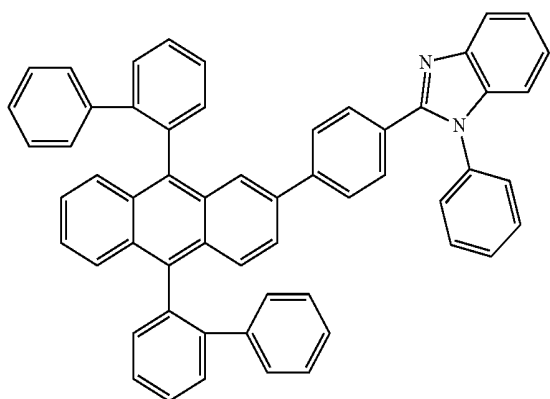
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ET7



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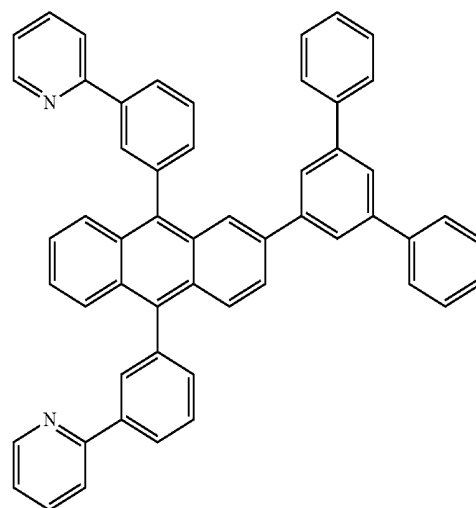
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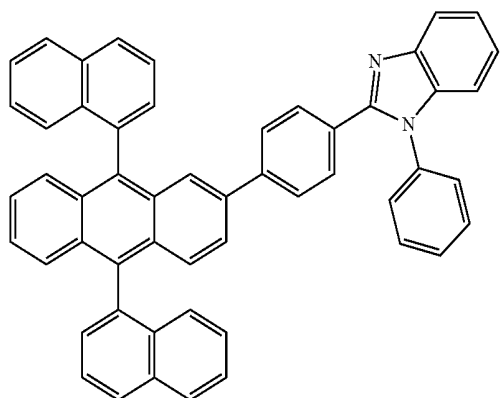
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ET8

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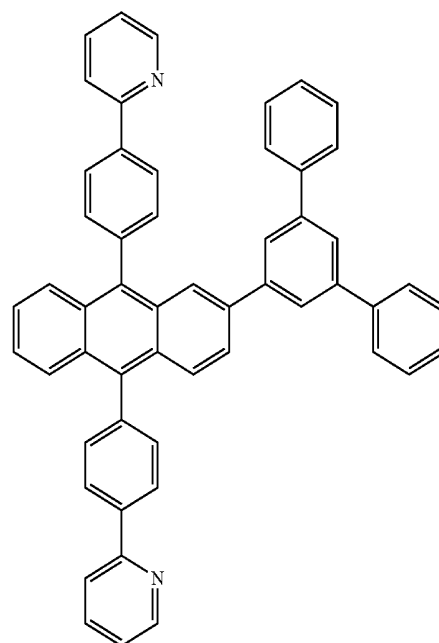
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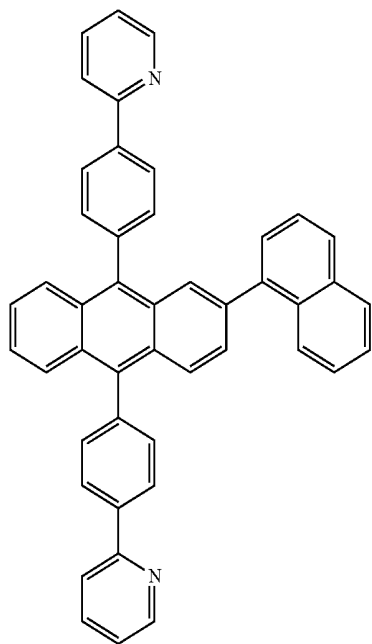
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ET9

115
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ET10

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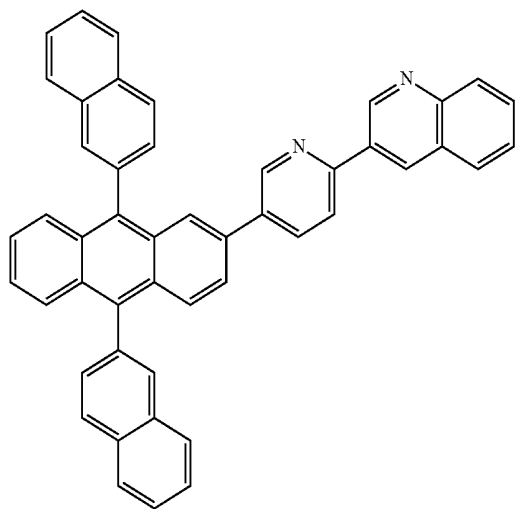
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ET11



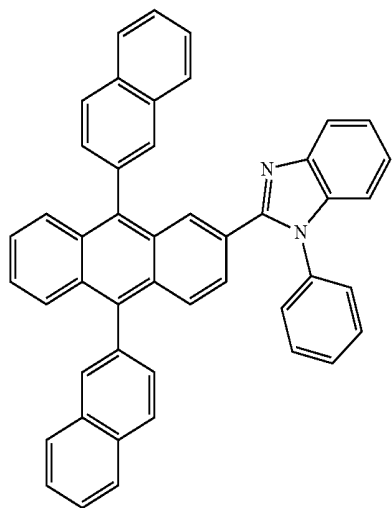
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ET12



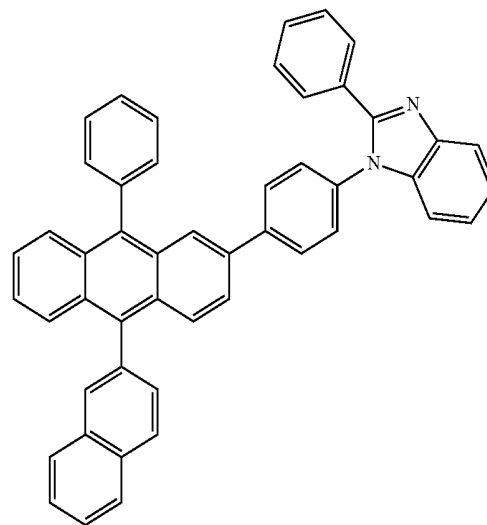
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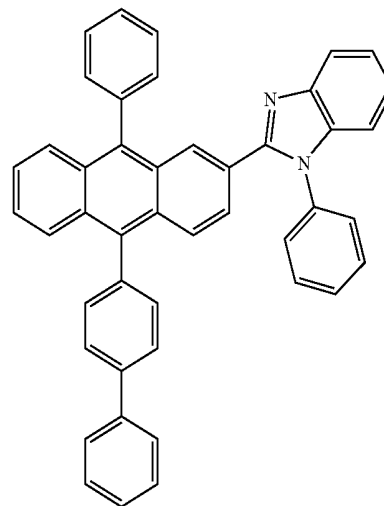
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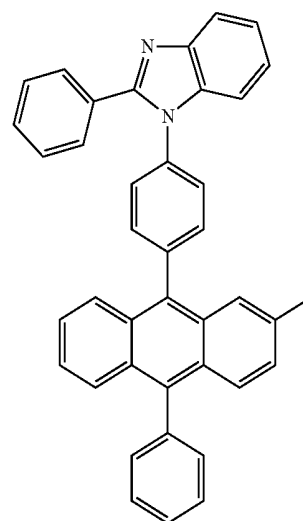
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ET13

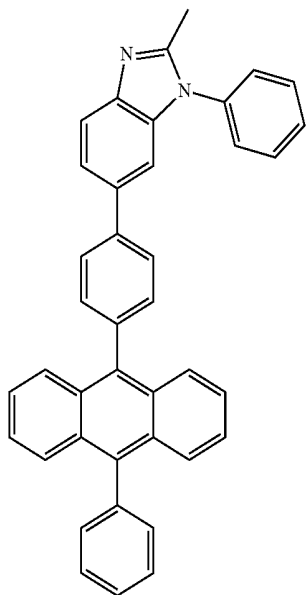
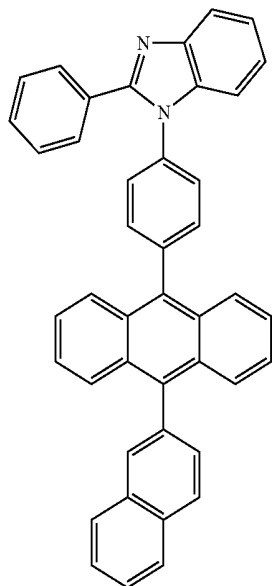
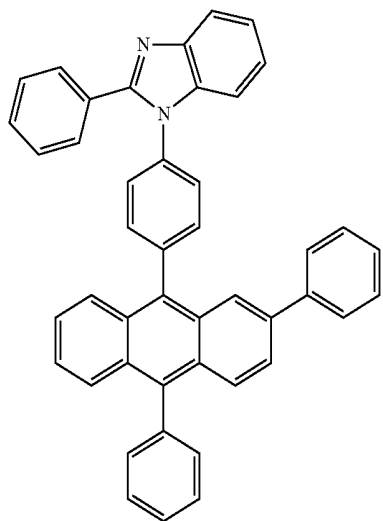


ET14



ET15

117
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118
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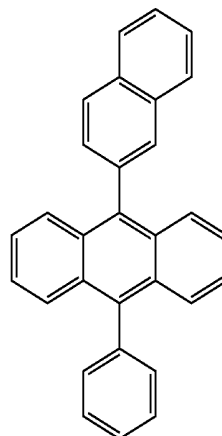
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ET19

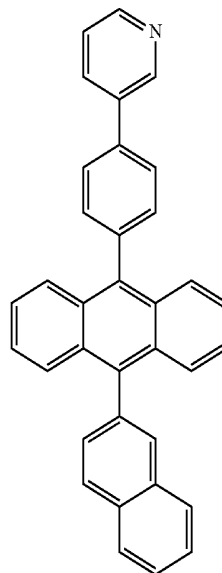
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ET20

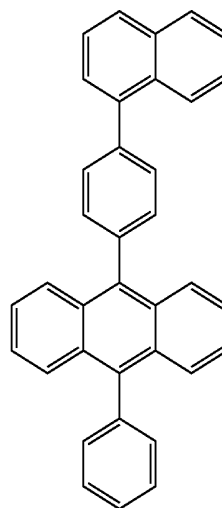
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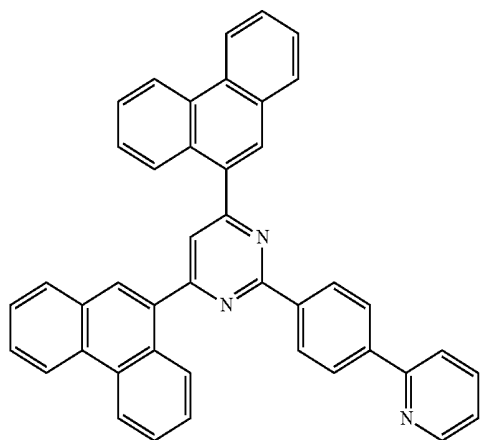
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ET21

119
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ET22

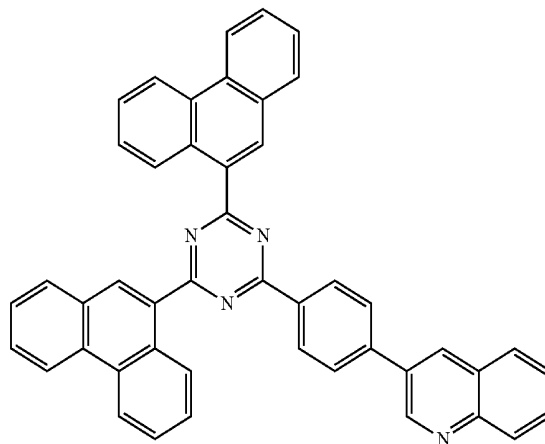
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ET25

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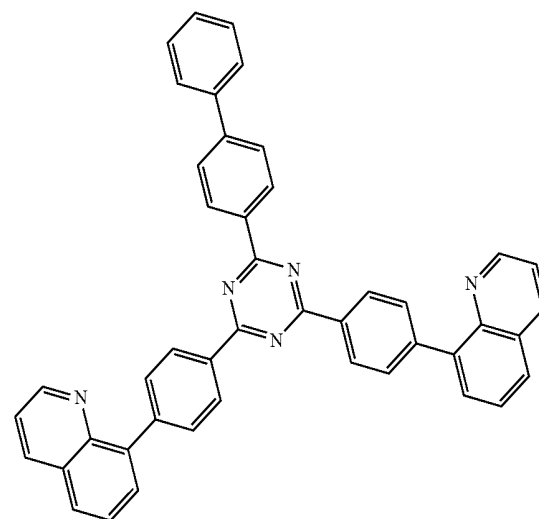
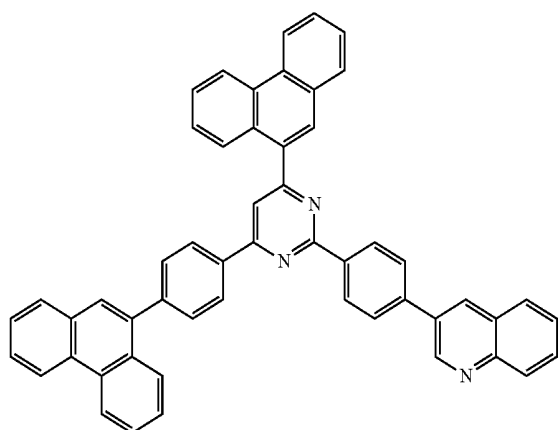
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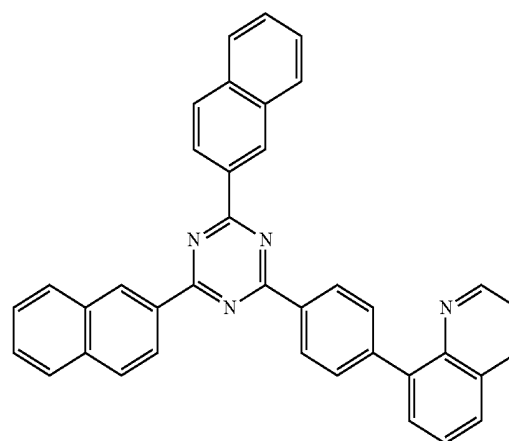
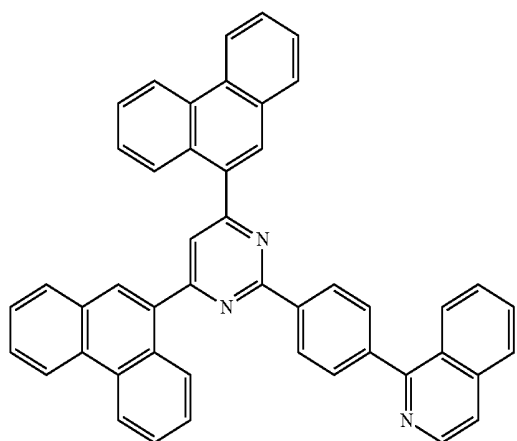
ET26

ET24 50

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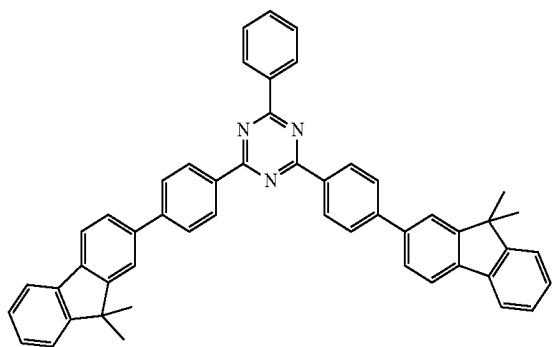
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ET27

121
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ET28

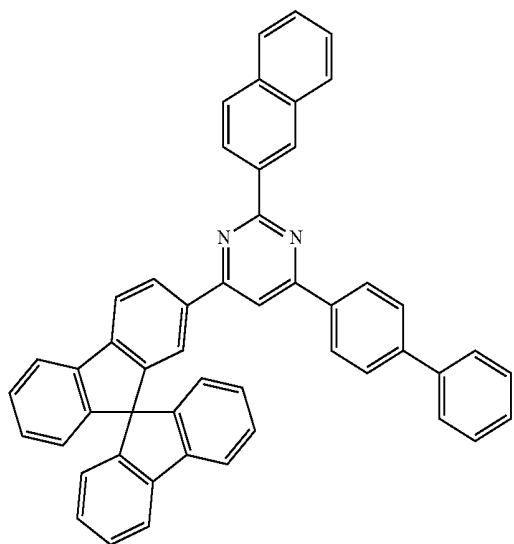
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ET29



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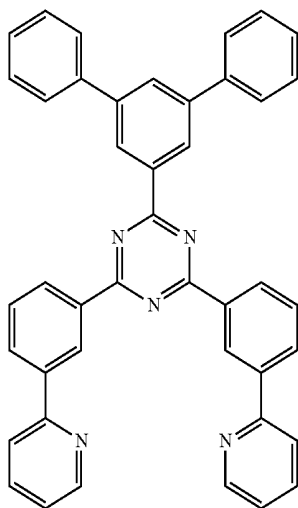
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ET30



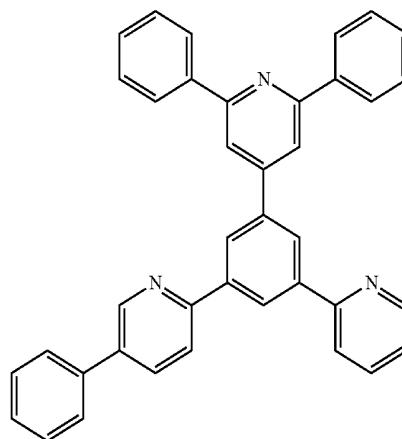
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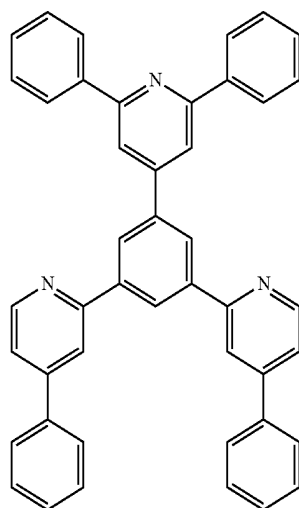
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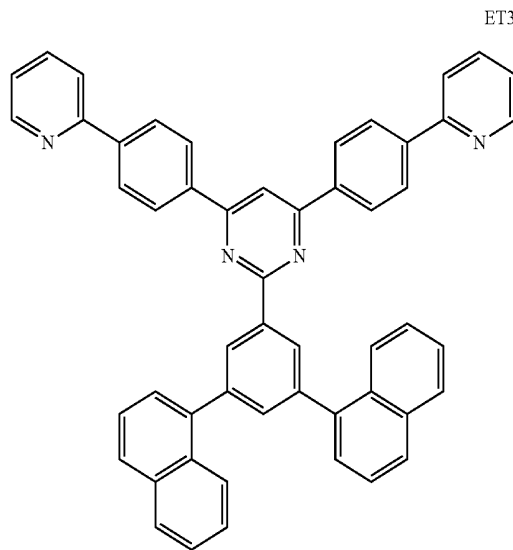
122
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ET31



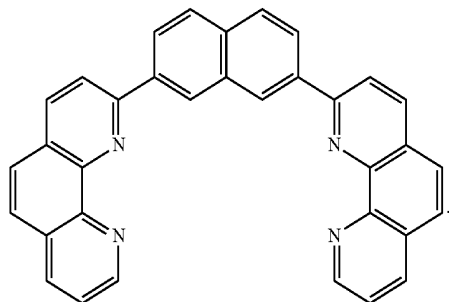
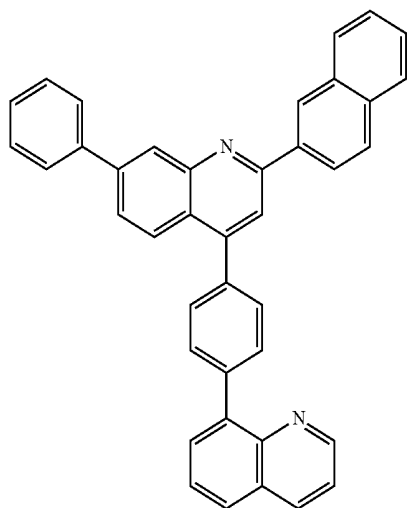
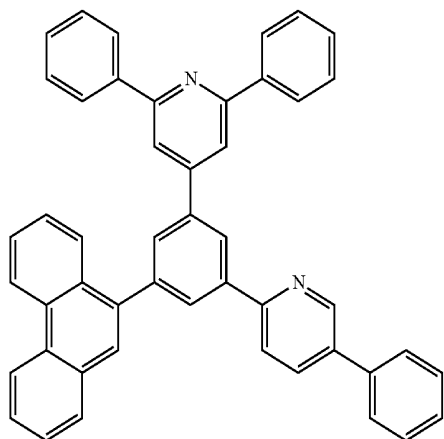
ET32



ET33

123

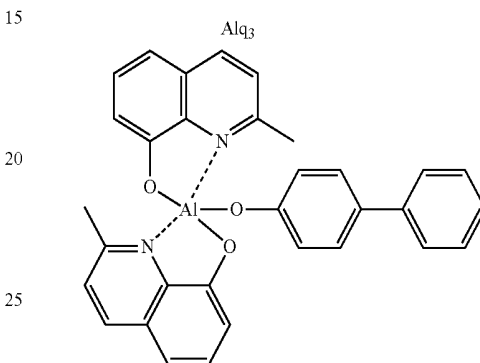
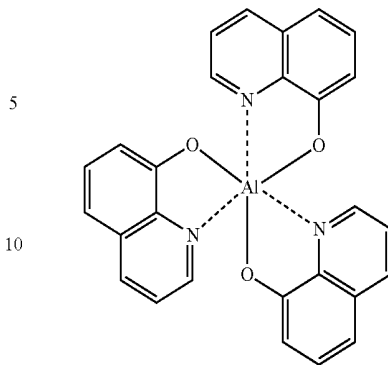
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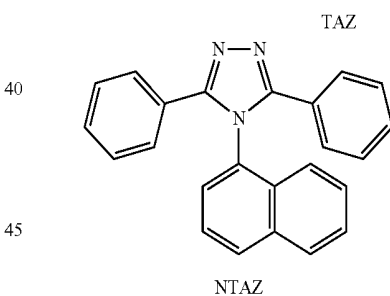
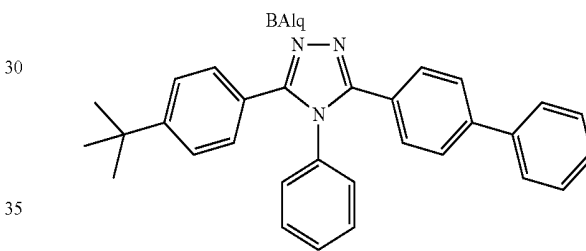
In one or more embodiments, the electron transport region may include at least one selected from 2,9-dimethyl-4,7-diphenyl-1,10-phenanthroline (BCP), 4,7-diphenyl-1,10-phenanthroline (Bphen), Alq₃, BALq, 3-(biphenyl-4-yl)-5-(4-tert-butylphenyl)-4-phenyl-4H-1,2,4-triazole (TAZ), and NTAZ.

124

ET34



ET35



ET36

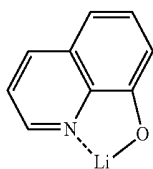
The thickness of the buffer layer, the hole blocking layer, or the electron controlling layer may each independently be in a range of about 20 Å to about 1,000 Å, e.g., about 30 Å to about 300 Å. When the thicknesses of the buffer layer, the hole blocking layer, and the electron control layer are within these ranges, the electron blocking layer may have excellent electron blocking characteristics or electron control characteristics without a substantial increase in driving voltage.

A thickness of the electron transport layer may be in a range of about 100 Å to about 1,000 Å, e.g., about 150 Å to about 500 Å. When the thickness of the electron transport layer is within the range described above, the electron transport layer may have satisfactory electron transport characteristics without a substantial increase in driving voltage.

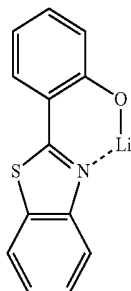
The electron transport region (e.g., the electron transport layer in the electron transport region) may further include, in addition to the materials described above, a metal-containing material.

The metal-containing material may include at least one selected from an alkali metal complex and an alkaline earth-metal complex. The alkali metal complex may include a metal ion selected from a Li ion, a Na ion, a K ion, a Rb ion, and a Cs ion, and the alkaline earth-metal complex may include a metal ion selected from a Be ion, a Mg ion, a Ca ion, a Sr ion, and a Ba ion. A ligand coordinated with the metal ion of the alkali metal complex or the alkaline earth-metal complex may be selected from a hydroxy quinoline, a hydroxy isoquinoline, a hydroxy benzoquinoline, a hydroxy acridine, a hydroxy phenanthridine, a hydroxy phenylan oxazole, a hydroxy phenylthiazole, a hydroxy diphenylan oxadiazole, a hydroxy diphenylthiadiazol, a hydroxy phenylpyridine, a hydroxy phenylbenzimidazole, a hydroxy phenylbenzothiazole, a bipyridine, a phenanthroline, and a cyclopentadiene.

In an implementation, the metal-containing material may include a Li complex. In an implementation, the Li complex may include, e.g., Compound ET-DI (lithium quinolate, LiQ) or ET-D2.



ET-DI



ET-D2

The electron transport region may include an electron injection layer that facilitates injection of electrons from the second electrode **190**. The electron injection layer may directly contact the second electrode **190**.

In an implementation, the electron injection layer may have i) a single-layered structure including a single layer including a single material, ii) a single-layered structure including a single layer including a plurality of different materials, or iii) a multi-layered structure having a plurality of layers including a plurality of different materials.

The electron injection layer may include an alkali metal, an alkaline earth metal, a rare-earth metal, an alkali metal compound, an alkaline earth-metal compound, a rare-earth metal compound, an alkali metal complex, an alkaline earth-metal complex, a rare-earth metal complex, or any combination thereof.

The alkali metal may be selected from Li, Na, K, Rb, and Cs. In one or more embodiments, the alkali metal may be Li, Na, or Cs. In an implementation, the alkali metal may be Li or Cs.

The alkaline earth metal may be selected from Mg, Ca, Sr, and Ba.

The rare-earth metal may be selected from Sc, Y, Ce, Tb, Yb, and Gd.

The alkali metal compound, the alkaline earth-metal compound, and the rare-earth metal compound may be selected from oxides and halides (for example, fluorides, chlorides, bromides, or iodides) of the alkali metal, the alkaline earth-metal, and the rare-earth metal.

The alkali metal compound may be selected from alkali metal oxides, such as Li_2O , Cs_2O , or K_2O , and alkali metal halides, such as LiF, NaF, CsF, KF, LiI, NaI, CsI, or KI. In an implementation, the alkali metal compound may be selected from LiF, Li_2O , NaF, LiI, NaI, CsI, and KI.

The alkaline earth-metal compound may be selected from alkaline earth-metal compounds, such as BaO, SrO, CaO, $\text{Ba}_x\text{Sr}_{1-x}\text{O}$ ($0 < x < 1$), or $\text{Ba}_x\text{Ca}_{1-x}\text{O}$ ($0 < x < 1$). In an implementation, the alkaline earth-metal compound may be selected from BaO, SrO, and CaO.

The rare-earth metal compound may be selected from YbF_3 , ScF_3 , ScO_3 , Y_2O_3 , Ce_2O_3 , GdF_3 , and TbF_3 . In an implementation, the rare-earth metal compound may be selected from YbF_3 , ScF_3 , TbF_3 , YbI_3 , ScI_3 , and TbI_3 .

In an implementation, the alkali metal complex, the alkaline earth-metal complex, and the rare-earth metal complex may include an ion of an alkali metal, an alkaline earth-metal, and a rare-earth metal as described above, and a ligand coordinated with a metal ion of the alkali metal complex, the alkaline earth-metal complex, and the rare-earth metal complex may each independently be selected from hydroxy quinoline, hydroxy isoquinoline, hydroxy benzoquinoline, hydroxy acridine, hydroxy phenanthridine, hydroxy phenylan oxazole, hydroxy phenylthiazole, hydroxy diphenylan oxadiazole, hydroxy diphenylthiadiazol, hydroxy phenylpyridine, hydroxy phenylbenzimidazole, hydroxy phenylbenzothiazole, bipyridine, phenanthroline, and cyclopentadiene.

The electron injection layer may consist of an alkali metal, an alkaline earth metal, a rare-earth metal, an alkali metal compound, an alkaline earth-metal compound, a rare-earth metal compound, an alkali metal complex, an alkaline earth-metal complex, a rare-earth metal complex, or any combination thereof, as described above. In one or more embodiments, the electron injection layer may further include an organic material. An alkali metal, an alkaline earth metal, a rare-earth metal, an alkali metal compound, an alkaline earth-metal compound, a rare-earth metal compound, an alkali metal complex, an alkaline earth-metal complex, a rare-earth metal complex, or any combination thereof may be homogeneously or non-homogeneously dispersed in a matrix including an organic material when the electron injection layer further includes the organic material.

A thickness of the electron injection layer may be in a range of about 1 Å to about 100 Å, e.g., about 3 Å to about 90 Å. When the thickness of the electron injection layer is within the range described above, the electron injection layer may have satisfactory electron injection characteristics without a substantial increase in driving voltage.

[Second Electrode **190**]

The second electrode **190** may be disposed on the organic layer **150** having such a structure. The second electrode **190** may be a cathode that is an electron injection electrode, and in this regard, a material for forming the second electrode **190** may be a material having a low work function, and such a material may be a metal, an alloy, an electrically conductive compound, or a combination thereof.

In an implementation, the second electrode **190** may include at least one selected from lithium (Li), silver (Si), magnesium (Mg), aluminum (Al), aluminum-lithium (Al—Li), calcium (Ca), magnesium-indium (Mg—In), magnesium-silver (Mg—Ag), ITO, and IZO. The second electrode

127

190 may be a transmissive electrode, a semi-transmissive electrode, or a reflective electrode.

The second electrode 190 may have a single-layered structure, or a multi-layered structure including two or more layers.

[Description of FIGS. 2 to 4]

An organic light-emitting device 20 of FIG. 2 includes a first capping layer 210, a first electrode 110, an organic layer 150, and a second electrode 190, which are sequentially stacked in this stated order. An organic light-emitting device 30 of FIG. 3 includes a first electrode 110, an organic layer 150, a second electrode 190, and a second capping layer 220, which are sequentially stacked in this stated order. An organic light-emitting device 40 of FIG. 4 includes a first capping layer 210, a first electrode 110, an organic layer 150, a second electrode 190, and a second capping layer 220, which are sequentially stacked in this stated order.

Regarding FIGS. 2 to 4, the first electrode 110, the organic layer 150, and the second electrode 190 may be understood by referring to the description presented in connection with FIG. 1.

In the organic layer 150 of each of the organic light-emitting devices 20 and 40, light generated in an emission layer may pass through the first electrode 110, which is a semi-transmissive electrode or a transmissive electrode, and the first capping layer 210 toward the outside, and in the organic layer 150 of each of the organic light-emitting devices 30 and 40, light generated in an emission layer may pass through the second electrode 190, which is a semi-transmissive electrode or a transmissive electrode, and the second capping layer 220 toward the outside.

The first capping layer 210 and the second capping layer 220 may help increase external luminescent efficiency according to the principle of constructive interference.

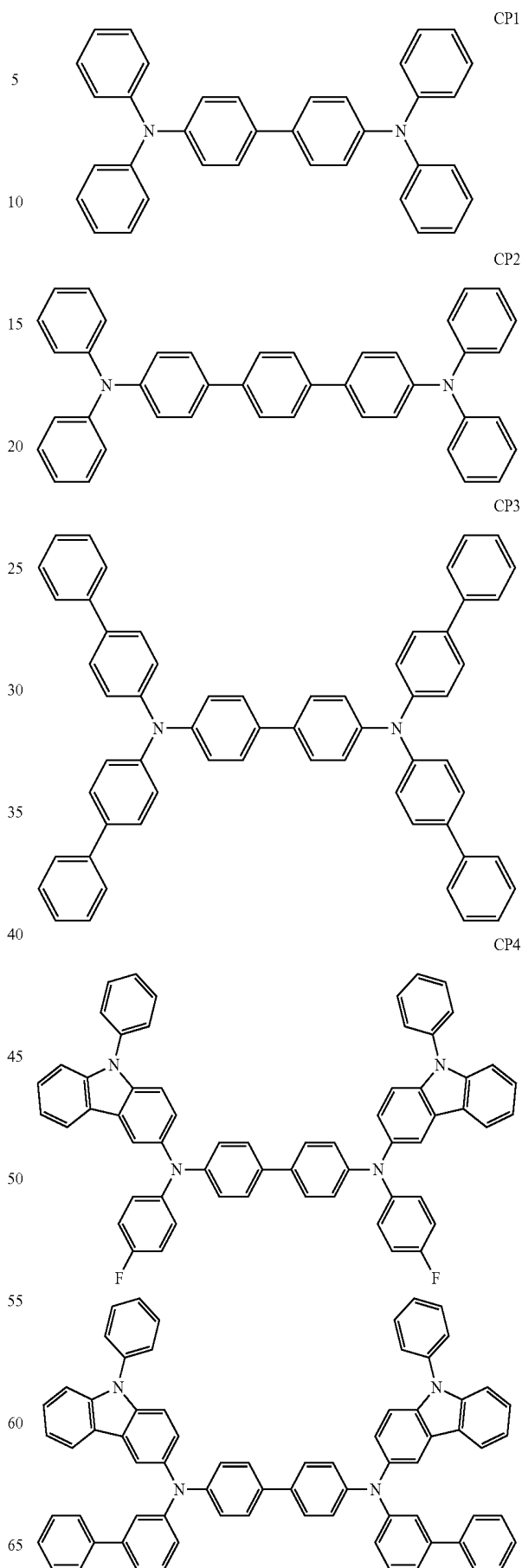
The first capping layer 210 and the second capping layer 220 may each independently be an organic capping layer including an organic material, an inorganic capping layer including an inorganic material, or a composite capping layer including an organic material and an inorganic material.

At least one selected from the first capping layer 210 and the second capping layer 220 may independently include at least one material selected from carbocyclic compounds, heterocyclic compounds, amine-based compounds, porphyrine derivatives, phthalocyanine derivatives, naphthalocyanine derivatives, alkali metal complexes, and alkaline earth-based complexes. A carbocyclic compound, a heterocyclic compound, and an amine-based compound selected therefrom may be optionally substituted with a substituent containing at least one element selected from O, N, S, Se, Si, F, Cl, Br, and I. In one or more embodiments, at least one selected from the first capping layer 210 and the second capping layer 220 may independently include an amine-based compound.

In one or more embodiments, at least one selected from the first capping layer 210 and the second capping layer 220 may independently include the compound represented by Formula 201 or the compound represented by Formula 202.

In an implementation, at least one selected from the first capping layer 210 and the second capping layer 220 may independently include a compound selected from Compounds HT28 to HT33 and Compounds CP1 to CP5.

128



Hereinbefore, the organic light-emitting device according to an embodiment has been described in connection with FIGS. 1-4.

Layers constituting the hole transport region, an emission layer, and layers constituting the electron transport region may be formed in a certain region by using one or more suitable methods selected from vacuum deposition, spin coating, casting, Langmuir-Blodgett (LB) deposition, ink-jet printing, laser printing, and laser-induced thermal imaging.

When the respective layers of the hole transport region, the respective layers of the electron transport region, and the emission layer are formed by deposition, the deposition may be performed at a deposition temperature of about 100° C. to about 500° C., at a vacuum pressure of about 10⁻⁸ torr to about 10⁻³ torr, and/or at a deposition rate of about 0.01 Å/sec to about 100 Å/sec by taking into account a material for forming a layer to be deposited, and the structure of a layer to be formed.

When layers constituting the hole transport region, an emission layer, and layers constituting the electron transport region are formed by spin coating, the spin coating may be performed at a coating speed of about 2,000 rpm to about 5,000 rpm and at a heat treatment temperature of about 80° C. to 200° C., depending on a material to be included in a layer and the structure of each layer to be formed.

[General Definition of Substituents]

The term “C₁-C₆₀ alkyl group” as used herein refers to a linear or branched saturated aliphatic hydrocarbon monovalent group having 1 to 60 carbon atoms, and non-limiting examples thereof include a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, a pentyl group, an iso-amyl group, and a hexyl group. The term “C₁-C₆₀ alkylene group” as used herein refers to a divalent group having the same structure as the C₁-C₆₀ alkyl group.

The term “C₂-C₆₀ alkenyl group” as used herein refers to a hydrocarbon group formed by substituting at least one carbon-carbon double bond in the middle or at the terminus of the C₂-C₆₀ alkyl group, and non-limiting examples thereof include an ethenyl group, a propenyl group, and a butenyl group. The term “C₂-C₆₀ alkenylene group” as used herein refers to a divalent group having the same structure as the C₂-C₆₀ alkenyl group.

The term “C₂-C₆₀ alkynyl group” as used herein refers to a hydrocarbon group formed by substituting at least one carbon-carbon triple bond in the middle or at the terminus of the C₂-C₆₀ alkyl group, and non-limiting examples thereof include an ethynyl group and a propynyl group. The term “C₂-C₆₀ alkynylene group” as used herein refers to a divalent group having the same structure as the C₂-C₆₀ alkynyl group.

The term “C₁-C₆₀ alkoxy group” as used herein refers to a monovalent group represented by —OA₁₀₁ (wherein A₁₀₁ is the C₁-C₆₀ alkyl group), and non-limiting examples thereof include a methoxy group, an ethoxy group, and an isopropoxy group.

The term “C₃-C₁₀ cycloalkyl group” as used herein refers to a monovalent saturated hydrocarbon monocyclic group having 3 to 10 carbon atoms, and non-limiting examples thereof include a cyclopropyl group, a cyclobutyl group, a cyclopentyl group, a cyclohexyl group, and a cycloheptyl group. The term “C₃-C₁₀ cycloalkylene group” as used herein refers to a divalent group having the same structure as the C₃-C₁₀ cycloalkyl group.

The term “C₁₀-C₁₀ heterocycloalkyl group” as used herein refers to a monovalent saturated monocyclic group having at least one heteroatom selected from N, O, Si, P, and

S as a ring-forming atom and 1 to 10 carbon atoms, and non-limiting examples thereof include a 1,2,3,4-oxatriazolindinyl group, a tetrahydrofuranyl group, and a tetrahydrothiophenyl group. The term “C₁-C₁₀ heterocycloalkylene group” as used herein refers to a divalent group having the same structure as the C₁-C₁₀ heterocycloalkyl group.

The term “C₃-C₁₀ cycloalkenyl group” as used herein refers to a monovalent monocyclic group that has 3 to 10 carbon atoms, at least one carbon-carbon double bond in the ring thereof, and no aromaticity, and non-limiting examples thereof include a cyclopentenyl group, a cyclohexenyl group, and a cycloheptenyl group. The term “C₃-C₁₀ cycloalkenylene group” as used herein refers to a divalent group having the same structure as the C₃-C₁₀ cycloalkenyl group.

The term “C₁-C₁₀ heterocycloalkenyl group” as used herein refers to a monovalent monocyclic group that has at least one heteroatom selected from N, O, Si, P, and S as a ring-forming atom, 1 to 10 carbon atoms, and at least one carbon-carbon double bond in its ring. Non-limiting examples of the C₁-C₁₀ heterocycloalkenyl group include a 4,5-dihydro-1,2,3,4-oxatriazolyl group, a 2,3-dihydrofuranyl group, and a 2,3-dihydrothiophenyl group. The term “C₁-C₁₀ heterocycloalkenylene group” as used herein refers to a divalent group having the same structure as the C₁-C₁₀ heterocycloalkenyl group.

The term “C₆-C₆₀ aryl group” as used herein refers to a monovalent group having a carbocyclic aromatic system having 6 to 60 carbon atoms, and the term “C₆-C₆₀ arylene group” as used herein refers to a divalent group having a carbocyclic aromatic system having 6 to 60 carbon atoms. Non-limiting examples of the C₆-C₆₀ aryl group include a phenyl group, a naphthyl group, an anthracenyl group, a phenanthrenyl group, a pyrenyl group, and a chrysenyl group. When the C₆-C₆₀ aryl group and the C₆-C₆₀ arylene group each include two or more rings, the rings may be fused to each other.

The term “C₁-C₆₀ heteroaryl group” as used herein refers to a monovalent group having a heterocyclic aromatic system that has at least one heteroatom selected from N, O, Si, P, and S as a ring-forming atom, in addition to 1 to 60 carbon atoms. The term “C₁-C₆₀ heteroarylene group” as used herein refers to a divalent group having a heterocyclic aromatic system that has at least one heteroatom selected from N, O, Si, P, and S as a ring-forming atom, in addition to 1 to 60 carbon atoms. Non-limiting examples of the C₁-C₆₀ heteroaryl group include a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, and an isoquinolinyl group. When the C₁-C₆₀ heteroaryl group and the C₁-C₆₀ heteroarylene group each include two or more rings, the rings may be fused to each other.

The term “C₆-C₆₀ aryloxy group” as used herein refers to —OA₁₀₂ (wherein A₁₀₂ is the C₆-C₆₀ aryl group), and the term “C₆-C₆₀ arylthio group” as used herein indicates —SA₁₀₃ (wherein A₁₀₃ is the C₆-C₆₀ aryl group).

The term “monovalent non-aromatic condensed polycyclic group” as used herein refers to a monovalent group (for example, having 8 to 60 carbon atoms) that has two or more rings condensed with each other, only carbon atoms as ring-forming atoms, and non-aromaticity in the entire molecular structure. A detailed example of the monovalent non-aromatic condensed polycyclic group is a fluorenyl group. The term “divalent non-aromatic condensed polycyclic group,” used herein, refers to a divalent group having the same structure as the monovalent non-aromatic condensed polycyclic group.

The term “monovalent non-aromatic condensed heteropolycyclic group” as used herein refers to a monovalent group (for example, having 1 to 60 carbon atoms) that has two or more rings condensed to each other, has at least one heteroatom selected from N, O, Si, P, and S, other than carbon atoms, as a ring-forming atom, and has non-aromaticity in the entire molecular structure. An example of the monovalent non-aromatic condensed heteropolycyclic group is a carbazolyl group. The term “divalent non-aromatic condensed heteropolycyclic group,” used herein, refers to a divalent group having the same structure as the monovalent non-aromatic condensed heteropolycyclic group.

The term “C₅-C₆₀ carbocyclic group” as used herein refers to a monocyclic or polycyclic group having 5 to 60 carbon atoms in which a ring-forming atom is a carbon atom only. The C₅-C₆₀ carbocyclic group may be an aromatic carbocyclic group or a non-aromatic carbocyclic group. The C₅-C₆₀ carbocyclic group may be a ring, such as benzene; a monovalent group, such as a phenyl group; or a divalent group, such as a phenylene group. In one or more embodiments, depending on the number of substituents connected to the C₅-C₆₀ carbocyclic group, the C₅-C₆₀ carbocyclic group may be a trivalent group or a quadrivalent group.

The term “C₁-C₆₀ heterocyclic group” as used herein refers to a group having the same structure as the C₁-C₆₀ carbocyclic group, except that as a ring-forming atom, at least one heteroatom selected from N, O, Si, P, and S is used in addition to carbon (the number of carbon atoms may be in a range of 1 to 60).

At least one substituent of the substituted C₅-C₆₀ carbocyclic group, the substituted C₁-C₆₀ heterocyclic group, the substituted C₃-C₁₀ cycloalkylene group, the substituted C₁-C₁₀ heterocycloalkylene group, the substituted C₃-C₁₀ cycloalkenylene group, the substituted C₁-C₁₀ heterocycloalkenylene group, the substituted C₆-C₆₀ arylene group, the substituted C₁-C₆₀ heteroarylene group, the substituted divalent non-aromatic condensed polycyclic group, the substituted divalent non-aromatic condensed heteropolycyclic group, the substituted C₁-C₆₀ alkyl group, the substituted C₂-C₆₀ alkenyl group, the substituted C₂-C₆₀ alkynyl group, the substituted C₁-C₆₀ alkoxy group, the substituted C₃-C₁₀ cycloalkyl group, the substituted C₁-C₁₀ heterocycloalkyl group, the substituted C₃-C₁₀ cycloalkenyl group, the substituted C₁-C₁₀ heterocycloalkenyl group, the substituted C₆-C₆₀ aryl group, the substituted C₆-C₆₀ aryloxy group, the substituted C₆-C₆₀ arylthio group, the substituted C₁-C₆₀ heteroaryl group, the substituted monovalent non-aromatic condensed polycyclic group, and the substituted monovalent non-aromatic condensed heteropolycyclic group may be selected from:

deuterium (-D), -F, -Cl, -Br, -I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, and a C₁-C₆₀ alkoxy group;

a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, and a C₁-C₆₀ alkoxy group, each substituted with at least one selected from deuterium, -F, -Cl, -Br, -I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₅-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group,

-Si(Q₁₁)(Q₁₂)(Q₁₃), -N(Q₁₁)(Q₁₂), -B(Q₁₁)(Q₁₂), -C(=O)(Q₁₁), -S(=O)₂(Q₁₁), and -P(=O)(Q₁₁)(Q₁₂);

a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;

a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group, each substituted with at least one selected from deuterium, -F, -Cl, -Br, -I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, -Si(Q₂₁)(Q₂₂)(Q₂₃), -N(Q₂₁)(Q₂₂), -B(Q₂₁)(Q₂₂), -C(=O)(Q₂₁), -S(=O)₂(Q₂₁), and -P(=O)(Q₂₁)(Q₂₂); and

-Si(Q₃₁)(Q₃₂)(Q₃₃), -N(Q₃₁)(Q₃₂), -B(Q₃₁)(Q₃₂), -C(=O)(Q₃₁), -S(=O)₂(Q₃₁), and -P(=O)(Q₃₁)(Q₃₂),

wherein Q₁₁ to Q₁₃, Q₂₁ to Q₂₃, and Q₃₁ to Q₃₃ may each independently be selected from hydrogen, deuterium, -F, -Cl, -Br, -I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group.

The term “Ph”, as used herein, may refer to a phenyl group; the term “Me”, as used herein, may refer to a methyl group; the term “Et”, as used herein, may refer to an ethyl group; the terms “ter-Bu” or “But”, as used herein, may refer to a tert-butyl group; and the term “OMe” as used herein may refer to a methoxy group.

The term “biphenyl group” as used therein refers to “a phenyl group substituted with a phenyl group.” In other words, a “biphenyl group” is a substituted phenyl group having a C₆-C₆₀ aryl group as a substituent.

The term “terphenyl group” as used herein refers to “a phenyl group substituted with a biphenyl group.” In other words, a “terphenyl group” is a phenyl group having, as a substituent, a C₆-C₆₀ aryl group substituted with a C₆-C₆₀ aryl group.

* and *¹ used herein, unless defined otherwise, each refer to a binding site to a neighboring atom in a corresponding formula.

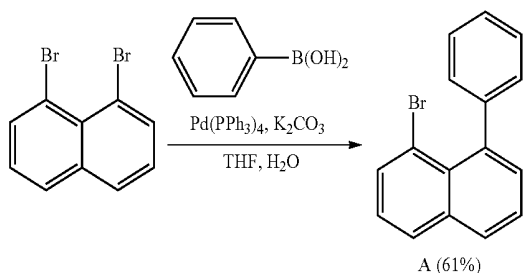
Hereinafter, a compound according to embodiments and an organic light-emitting device according to embodiments will be described in detail with reference to Synthesis Examples and Examples. The wording “B was used instead of A” used in describing Synthesis Examples indicates that an identical molar equivalent of B was used in place of A.

133

The following Examples and Comparative Examples are provided in order to highlight characteristics of one or more embodiments, but it will be understood that the Examples and Comparative Examples are not to be construed as limiting the scope of the embodiments, nor are the Comparative Examples to be construed as being outside the scope of the embodiments. Further, it will be understood that the embodiments are not limited to the particular details described in the Examples and Comparative Examples.

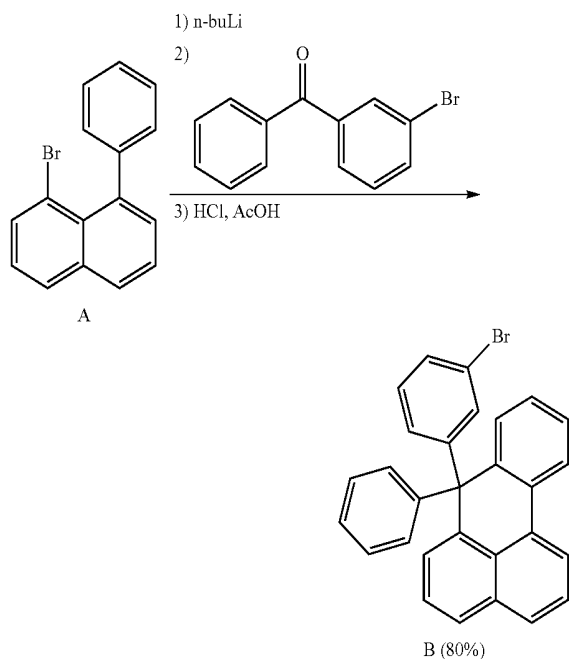
EXAMPLE

Synthesis Example 1: Synthesis of Compound 4



Synthesis of Intermediate A

Under an Ar atmosphere, 8.65 g of 1,8-dibromonaphthalene, 3.69 g of phenylboronic acid, 1.75 g of Pd(PPh₃)₄, and 3.55 g of K₂CO₃ were dissolved in a mixed solvent containing 90 mL of water and 300 mL of tetrahydrofuran (THF) and then refluxed and stirred for 6 hours in a 500-mL three-neck flask. An organic layer obtained therefrom was dried by using MgSO₄, and the solvent was evaporated. The residue obtained therefrom was separated and purified by silica gel column chromatography, thereby completing the preparation of 5.23 g (61%) of Intermediate A. A molecular weight of the prepared Intermediate A was measured to be 283 by MS/FAB.

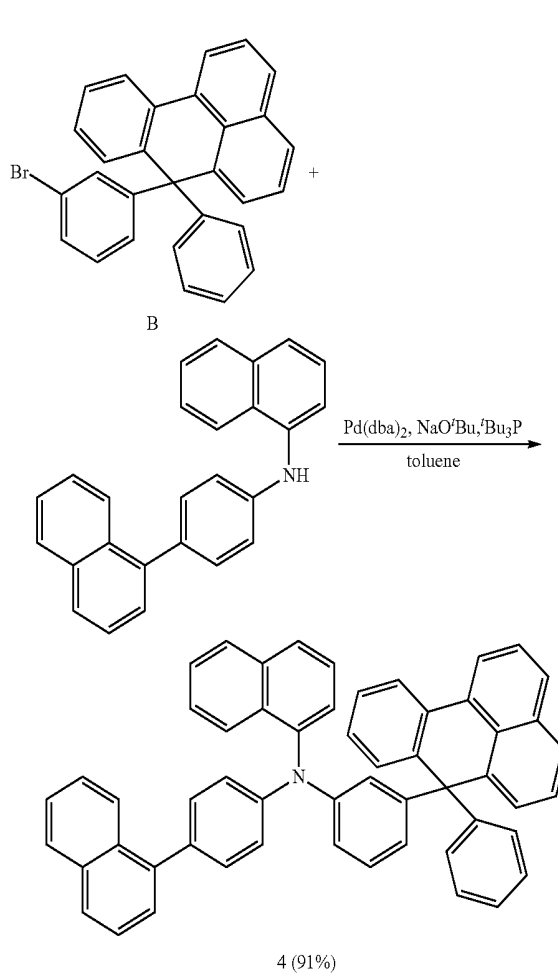


Synthesis of Intermediate B

1.00 g of Intermediate A was dissolved in 45 mL of dehydrated THF and stirred at a temperature of -78° C. in

134

a 200-mL three-neck flask. 2.65 mL of 1.6 M n-BuLi (in a hexane solvent) was added dropwise thereto and stirred for 2 hours. Then, 35 mL of a THF solution containing 1.10 g of 3-bromobenzophenone was added dropwise thereto and then further stirred at ambient temperature for 3 hours. A 1N hydrochloric acid aqueous solution was added to the mixed solution and stirred for 1 hour, and a washing process was performed thereon by using water. A solvent of an organic layer obtained therefrom was evaporated to obtain a white solid. The obtained white solid, 50 mL of AcOH, and 0.6 mL of hydrochloric acid were added to a 200-mL three-neck flask and heated and stirred at a temperature of 130° C. for 2 hours under a nitrogen atmosphere. The obtained mixed solution was added dropwise into 100 mL of cold water to obtain a white crystal. The obtained white crystal was washed by using MeOH and then dried, thereby completing the preparation of 1.26 g (80%) of Intermediate B. A molecular weight of the prepared Intermediate B was measured to be 447 by MS/FAB.



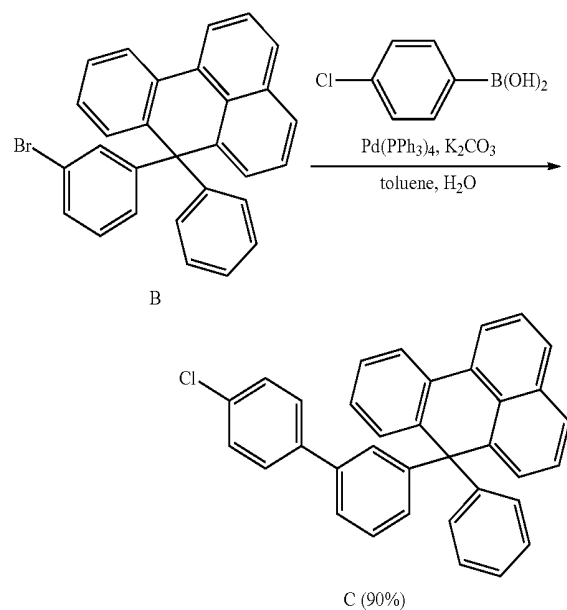
Synthesis of Compound 4

Under an Ar atmosphere, 1.50 g of Intermediate B, 1.14 g of N-[4-(1-naphthalenyl)phenyl]-1-naphthalenamine, 0.079 g of Pd(dba)₂, 0.53 g of NaOtBu, and 0.021 g of tBu₃P were dissolved in 55 mL of toluene and then refluxed and stirred for 6 hours in a 300-mL three-neck flask while

135

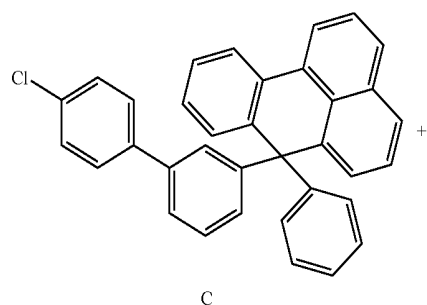
beating heated. After the stirred solution was cooled, an organic layer obtained therefrom was dried by using MgSO_4 , and a solvent was evaporated. The residue obtained therefrom was separated and purified by silica gel column chromatography, thereby completing the preparation of 2.13 g (90%) of Compound 4. The prepared Compound 4 was identified by MS/FAB and ^1H NMR.

Synthesis Example 2: Synthesis of Compound 10



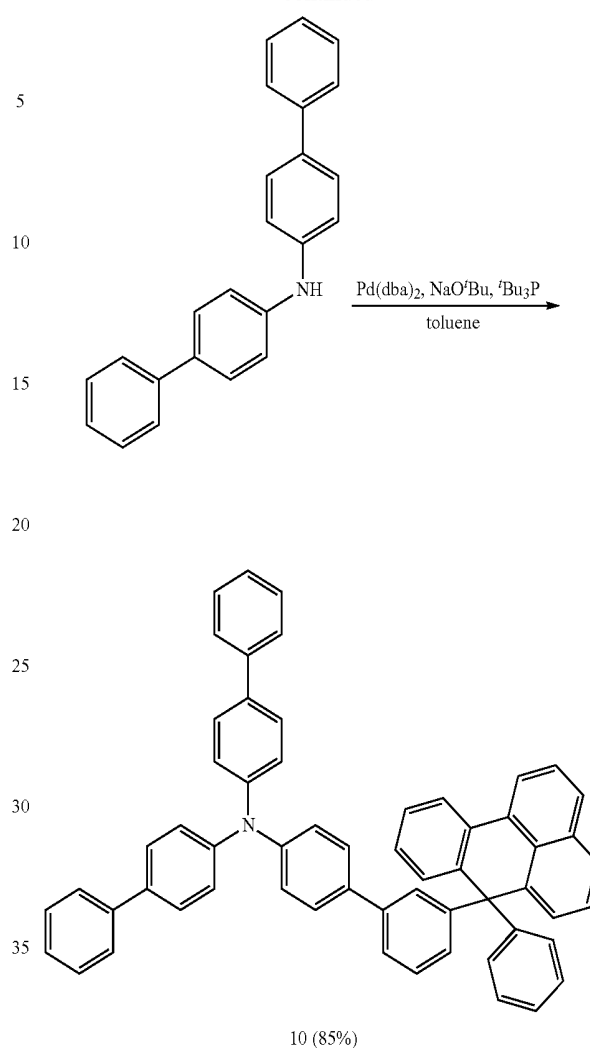
Synthesis of Intermediate C

Under an Ar atmosphere, 4.47 g of Intermediate B, 1.56 g of a 4-chlorophenylboronic acid, 0.610 g of $\text{Pd}(\text{PPh}_3)_4$, and 4.48 g of K_2CO_3 were refluxed and stirred in a mixed solution containing 15 mL of water, 20 mL of EtOH, and 100 mL of toluene in a 300-mL three-neck flask while being heated. After the stirred solution was cooled, an organic layer was separated by adding water thereto, and a solvent was evaporated. The residue obtained therefrom was separated and purified by silica gel column chromatography (a mixed solution containing toluene and hexane was used), thereby completing the preparation of 4.31 g (90%) of Intermediate C as a faintly yellow solid. A molecular weight of the prepared Intermediate C was measured to be 479 by MS/FAB.



136

-continued



Synthesis of Compound 10

Under an Ar atmosphere, 4.79 g of Intermediate C, 3.47 g of bis(4-biphenyl)amine, 0.440 g of $\text{Pd}(\text{dba})_2$, 7.21 g of NaOtBu , and 0.21 g of $t\text{Bu}_3\text{P}$ were dissolved in 110 mL of toluene and then refluxed and stirred for 6 hours in a 500-mL three-neck flask while being heated. After the stirred solution was cooled, an organic layer obtained therefrom was dried by using MgSO_4 , and a solvent was evaporated. The residue obtained therefrom was separated and purified by silica gel column chromatography, thereby completing the preparation of 6.70 g (85%) of Compound 10 as a faintly yellow solid. The prepared Compound 10 was identified by MS/FAB and ^1H NMR.

Synthesis Example 3: Synthesis of Compound 12

6.66 g (83%) of Compound 12 was synthesized in the same manner as in the synthesis of Compound 10, except that N-[4-(1-naphthalenyl)phenyl]-1-naphthalenamine was used instead of bis(4-biphenyl)amine. The synthesized Compound 12 was identified by MS/FAB and ^1H NMR.

Synthesis Example 4: Synthesis of Compound 18

6.31 g (77%) of Compound 18 was synthesized in the same manner as in the synthesis of Compound 4, except that 4-bromobenzophenone was used instead of 3-bromobenzophenone and bis(4-biphenyl)amine was used instead of N-[4-(1-naphthalenyl)phenyl]-1-naphthalenamine. The synthesized Compound 18 was identified by MS/FAB and ¹H NMR.

Synthesis Example 5: Synthesis of Compound 19

6.46 g (83%) of Compound 19 was synthesized in the same manner as in the synthesis of Compound 4, except that 4-bromobenzophenone was used instead of 3-bromobenzophenone and 4-(1-naphthalenyl)-N-[4-(1-naphthalenyl)phenyl]-benzenamine was used instead of N-[4-(1-naphthalenyl)phenyl]-1-naphthalenamine. The synthesized Compound 19 was identified by MS/FAB and ¹H NMR.

Synthesis Example 6: Synthesis of Compound 26

6.42 g (85%) of Compound 26 was synthesized in the same manner as in the synthesis of Compound 12, except that 4-bromobenzophenone was used instead of 3-bromobenzophenone and bis(4-biphenyl)amine was used instead of N-[4-(1-naphthalenyl)phenyl]-1-naphthalenamine. The synthesized Compound 26 was identified by MS/FAB and ¹H NMR.

¹H NMR and MS/FAB of Compounds synthesized in Synthesis Examples 1 to 6 are shown in Table 1.

Synthesis methods of Compounds other than Compounds shown in Table 1 may also be easily recognizable by one of ordinary skill in the art by referring to the synthesis routes and source materials.

TABLE 1

Compound	¹ H NMR (CDCl ₃ , 500 MHz)	HR-EIMS	
		found	calc.
4	8.37 (d, 1H, J = 7.82 Hz), 8.25 (d, 1H, J = 7.80 Hz), 8.02-7.88 (m, 3H), 7.65-7.62 (m, 5H), 7.58-7.43 (m, 11H), 7.41-7.25 (m, 10H), 7.21-7.11 (m, 6H)	711.2941	711.2926
10	8.26 (d, 1H, J = 7.80 Hz), 8.11 (d, 1H, J = 7.80 Hz), 8.04-7.93 (m, 8H), 7.85-7.77 (m, 6H), 7.65-7.45 (m, 12H), 7.35-7.22 (m, 11H)	763.3233	763.3239
12	8.41 (d, 1H, J = 7.82 Hz), 8.25 (dd, 4H, J = 7.20 Hz), 8.25 (d, 1H, J = 7.80 Hz), 8.02-7.89 (m, 3H), 7.69-7.62 (m, 5H), 7.48-7.43 (m, 11H), 7.41-7.25 (m, 10H), 7.18-7.02 (m, 6H)	787.3244	787.3239
18	8.28 (d, 1H, J = 7.82 Hz), 8.15 (d, 1H, J = 7.80 Hz), 8.02-7.89 (m, 8H), 7.85-7.69 (m, 6H), 7.62-7.55 (m, 10H), 7.40-7.35 (m, 9H)	687.2920	687.2926
19	8.27 (d, 1H, J = 7.82 Hz), 8.15 (d, 1H, J = 7.70 Hz), 8.02-7.90 (m, 8H), 7.85-7.69 (m, 6H), 7.55-7.45 (m, 12H), 7.30-7.22 (m, 11H)	787.3239	787.3239
26	8.25 (d, 1H, J = 7.82 Hz), 8.10 (d, 1H, J = 7.80 Hz), 8.04-7.93 (m, 8H), 7.85-7.77 (m, 6H), 7.65-7.45 (m, 12H), 7.34-7.22 (m, 11H)	763.3238	763.3239

Example 1

An anode was prepared by cutting a 15 Ωcm² ITO glass substrate (manufactured by Corning), having a thickness of 1,500 Å, to a size of 50 mm×50 mm×0.7 mm, ultrasonically cleaning the ITO glass substrate by using isopropyl alcohol and pure water each for 5 minutes, and then, exposing the ITO glass substrate to UV irradiation and ozone for 30 minutes to clean the ITO glass substrate. Then, the ITO glass substrate was loaded into a vacuum deposition apparatus.

2-TNATA was vacuum-deposited on the ITO glass substrate (anode) to form a hole injection layer having a thickness of 600 Å, and Compound 4 was vacuum-deposited on the hole injection layer to form a hole transport layer having a thickness of 300 Å, thereby forming a hole transport region.

ADN (host) and TBP (dopant) were co-deposited on the hole transport region at a weight ratio of 97:3 to form an emission layer having a thickness of 250 Å.

Alq₃ was deposited on the emission layer to form an electron transport layer having a thickness of 250 Å, LiF was deposited on the electron transport layer to form an electron injection layer having a thickness of 10 Å, and then, Al was vacuum-deposited on the electron injection layer to form a cathode (cathode electrode) having a thickness of 1,000 Å, thereby completing the manufacture of an organic light-emitting device.

Examples 2 to 6 and Comparative Examples 1 to 10

Organic light-emitting devices of Examples 2 to 6 and Comparative Examples 1 to 10 were manufactured in the same manner as in Example 1, except that Compounds shown in Table 2 were each used in forming a hole transport layer.

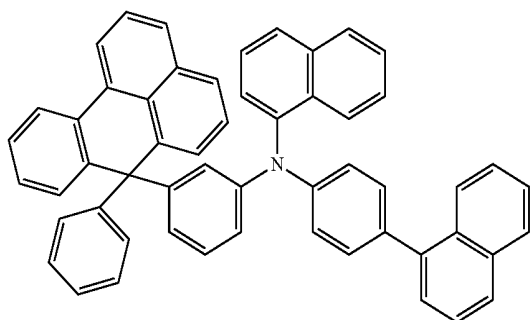
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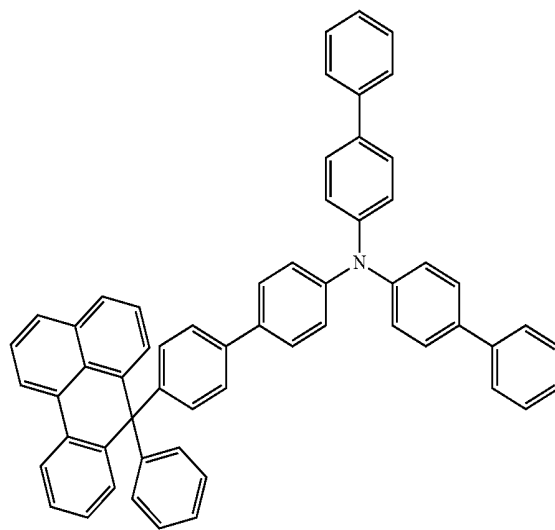
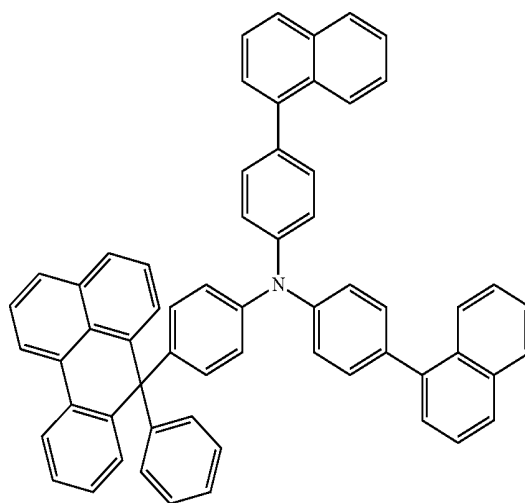
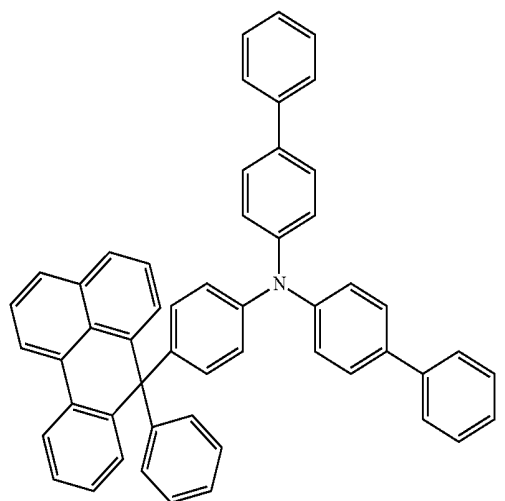
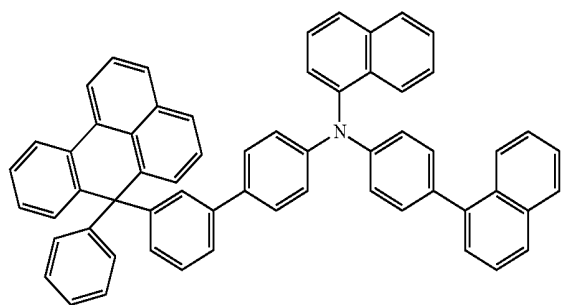
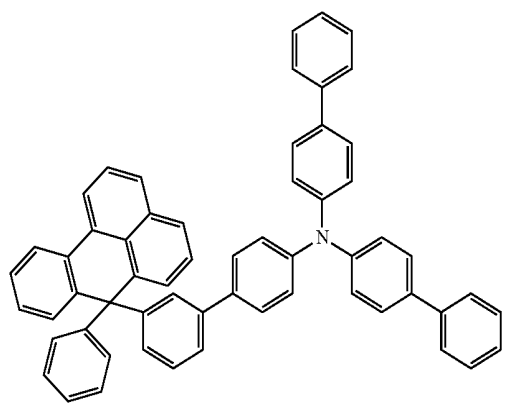
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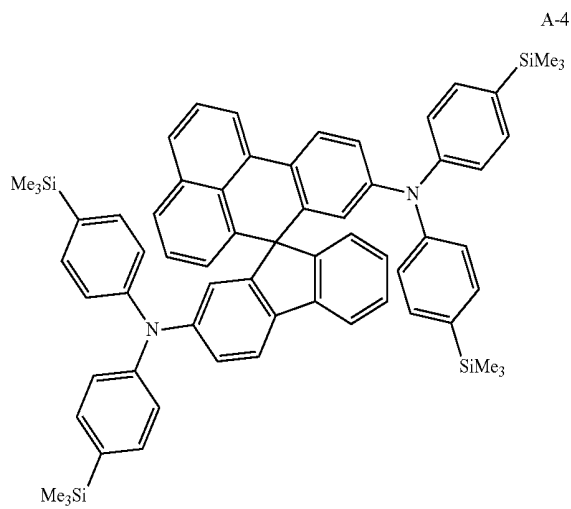
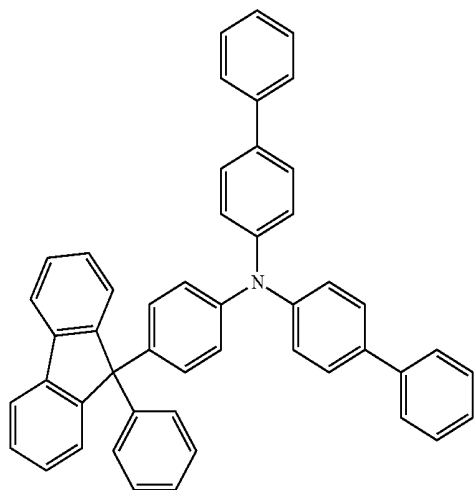
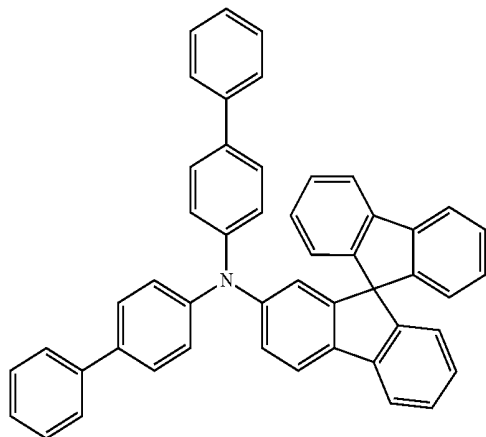
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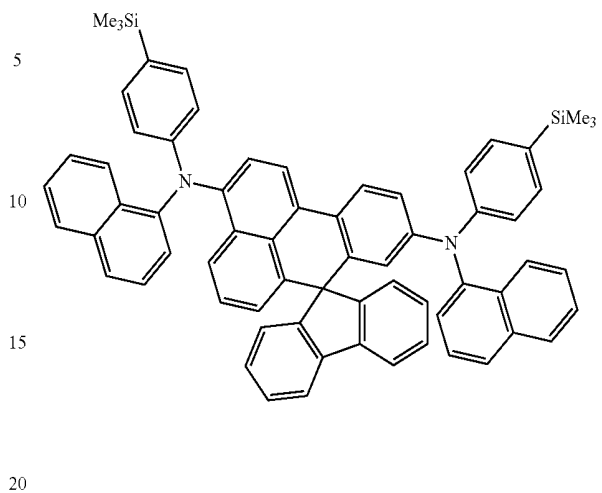
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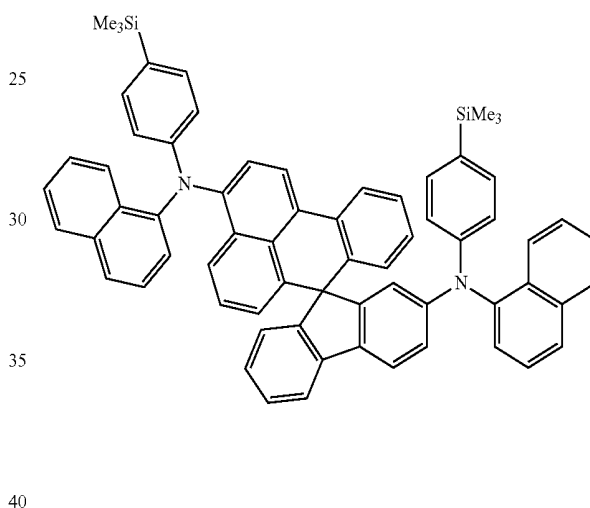
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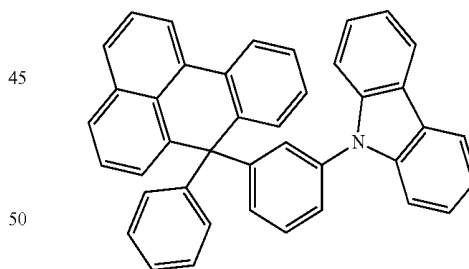
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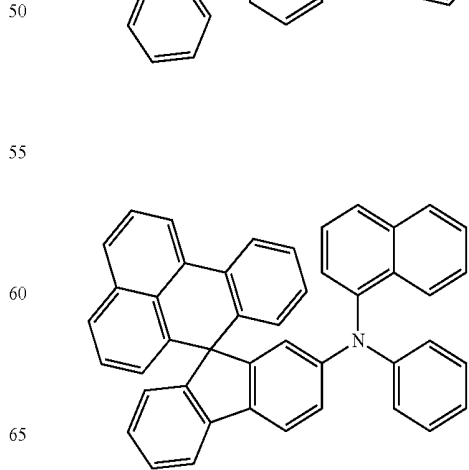
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143

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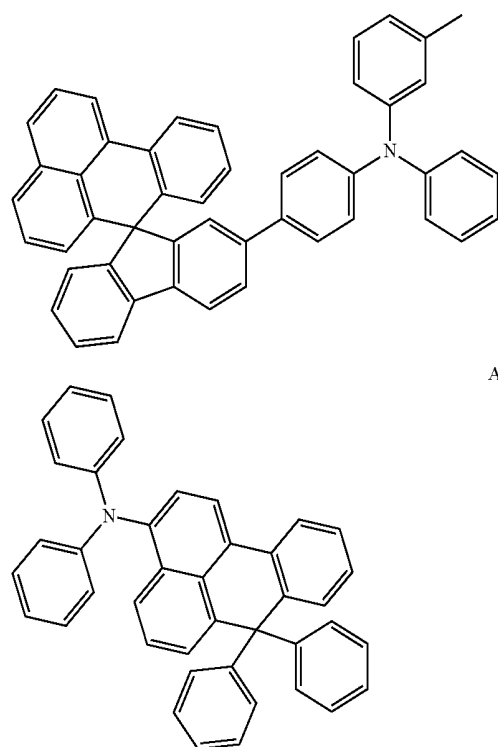


TABLE 2

	Material for hole transport layer	Driving voltage (V)	Current density (mA/cm ²)	Efficiency (cd/A)	Emission color	Half lifespan (hr @ 10 mA/cm ²)
Example 1	Compound 4	5.6	10	6.8	Blue	1,800 hr
Example 2	Compound 10	5.5	10	6.6	Blue	1,900 hr
Example 3	Compound 12	5.6	10	6.6	Blue	1,900 hr
Example 4	Compound 18	5.4	10	6.6	Blue	1,900 hr
Example 5	Compound 19	5.6	10	6.8	Blue	1,800 hr
Example 6	Compound 26	5.4	10	6.6	Blue	1,900 hr
Comparative Example 1	A-1	6.2	10	5.2	Blue	1,500 hr
Comparative Example 2	A-2	6.5	10	5.1	Blue	1,510 hr
Comparative Example 3	A-3	6.2	10	5.2	Blue	1,500 hr
Comparative Example 4	A-4	6.4	10	5.3	Blue	1,520 hr
Comparative Example 5	A-5	6.2	10	5.3	Blue	1,500 hr
Comparative Example 6	A-6	6.4	10	5.1	Blue	1,520 hr
Comparative Example 7	A-7	6.6	10	5.1	Blue	1,530 hr
Comparative Example 8	A-8	6.7	10	5.6	Blue	1,580 hr
Comparative Example 9	A-9	6.6	10	5.6	Blue	1,580 hr
Comparative Example 10	A-10	6.7	10	5.1	Blue	1,590 hr

Referring to Table 2, it may be seen that the organic light-emitting devices of Examples 1 to 6 had excellent

144

driving voltage, efficiency, and half lifespan, as compared with those of Comparative Examples 1 to 10.

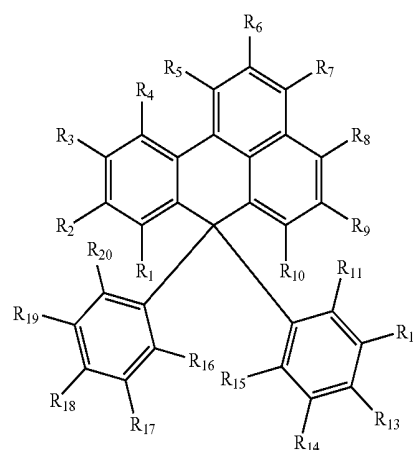
According to one or more embodiments, an organic light-emitting device including the condensed cyclic compound may have a low driving voltage, high efficiency, and a long lifespan.

Example embodiments have been disclosed herein, and although specific terms are employed, they are used and are to be interpreted in a generic and descriptive sense only and not for purpose of limitation. In some instances, as would be apparent to one of ordinary skill in the art as of the filing of the present application, features, characteristics, and/or elements described in connection with a particular embodiment may be used singly or in combination with features, characteristics, and/or elements described in connection with other embodiments unless otherwise specifically indicated. Accordingly, it will be understood by those of skill in the art that various changes in form and details may be made without departing from the spirit and scope of the present invention as set forth in the following claims.

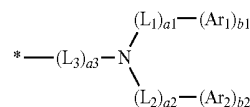
What is claimed is:

1. A condensed cyclic compound represented by Formula 1:

<Formula 1>



<Formula 2>



wherein, in Formulae 1 and 2,

L_1 to L_3 are each independently a substituted or unsubstituted C_3 - C_{60} carbocyclic group or a substituted or unsubstituted C_1 - C_{60} heterocyclic group,

a_1 is an integer of 0 to 3, wherein when a_1 is 2 or 3, the 2 or 3 L_1 (s) are identical to or different from each other, a_2 is an integer of 0 to 3, wherein when a_2 is 2 or 3, the 2 or 3 L_2 (s) are identical to or different from each other, and a_3 is an integer of 0 to 3, wherein when a_3 is 2 or 3, the 2 or 3 L_3 (s) are identical to or different from each other,

Ar_1 and Ar_2 are each independently selected from a substituted or unsubstituted C_3 - C_{10} cycloalkyl group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3 - C_{10} cycloalkenyl group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6 - C_{60} aryl group, a substi-

tuted or unsubstituted C₆-C₆₀ aryloxy group, a substituted or unsubstituted C₆-C₆₀ arylthio group, a substituted or unsubstituted C₁-C₆₀ heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group,

b1 is an integer of 0 to 3, wherein when b1 is 2 or 3, the 2 or 3 Ar₁(s) are identical to or different from each other, and b2 is an integer of 0 to 3, wherein when b2 is 2 or 3, the 2 or 3 Ar₂(s) are identical to or different from each other,

R₁ to R₂₀ are each independently selected from a group represented by Formula 2, hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a substituted or unsubstituted C₁-C₆₀ alkyl group, a substituted or unsubstituted C₂-C₆₀ alkenyl group, a substituted or unsubstituted C₂-C₆₀ alkynyl group, a substituted or unsubstituted C₁-C₆₀ alkoxy group, a substituted or unsubstituted C₃-C₁₀ cycloalkyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkyl group, a substituted or unsubstituted C₃-C₁₀ cycloalkenyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkenyl group, a substituted or unsubstituted C₆-C₆₀ aryl group, a substituted or unsubstituted C₆-C₆₀ aryloxy group, a substituted or unsubstituted C₆-C₆₀ arylthio group, a substituted or unsubstituted C₁-C₆₀ heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —Si(Q₁)(Q₂)(Q₃), —B(Q₁)(Q₂), —C(=O)(Q₁), —S(=O)₂(Q₁), and —P(=O)(Q₁)(Q₂), provided that R₁ to R₁₀ are not a group represented by Formula 2,

at least one selected from R₁₁ to R₂₀ is a group represented by Formula 2,

wherein, in Formulae 1 and 2,

at least one substituent of the substituted C₃-C₆₀ carbocyclic group, the substituted C₁-C₆₀ heterocyclic group, the substituted C₁-C₆₀ alkyl group, the substituted C₂-C₆₀ alkenyl group, the substituted C₂-C₆₀ alkynyl group, the substituted C₁-C₆₀ alkoxy group, the substituted C₃-C₁₀ cycloalkyl group, the substituted C₁-C₁₀ heterocycloalkyl group, the substituted C₃-C₁₀ cycloalkenyl group, the substituted C₁-C₁₀ heterocycloalkenyl group, the substituted C₆-C₆₀ aryl group, the substituted C₆-C₆₀ aryloxy group, the substituted C₆-C₆₀ arylthio group, the substituted C₁-C₆₀ heteroaryl group, the substituted monovalent non-aromatic condensed polycyclic group, and the substituted monovalent non-aromatic condensed heteropolycyclic group is selected from:

deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, and a C₁-C₆₀ alkoxy group;

a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, and a C₁-C₆₀ alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazino group, a hydrazono group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group;

erocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —Si(Q₁₁)(Q₁₂)(Q₁₃), —B(Q₁₁)(Q₁₂), —C(=O)(Q₁₁), —S(=O)₂(Q₁₁), and —P(=O)(Q₁₁)(Q₁₂);

a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group;

a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, a terphenyl group, —Si(Q₂₁)(Q₂₂)(Q₂₃), —B(Q₂₁)(Q₂₂), —C(=O)(Q₂₁), —S(=O)₂(Q₂₁), and —P(=O)(Q₂₁)(Q₂₂); and

—Si(Q₃₁)(Q₃₂)(Q₃₃), —B(Q₃₁)(Q₃₂), —C(=O)(Q₃₁), —S(=O)₂(Q₃₁), and —P(=O)(Q₃₁)(Q₃₂);

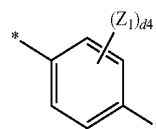
Q₁ to Q₃, Q₁₁ to Q₁₃, Q₂₁ to Q₂₃, and Q₃₁ to Q₃₃ are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group, and

* indicates a binding site to a neighboring atom.

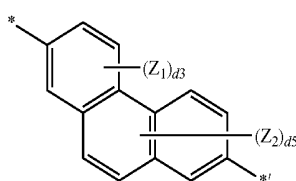
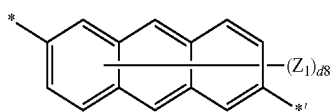
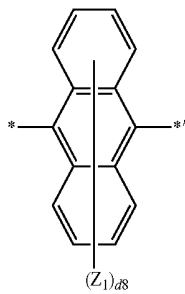
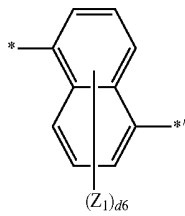
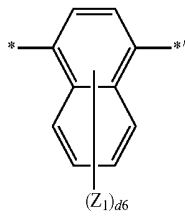
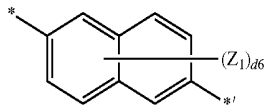
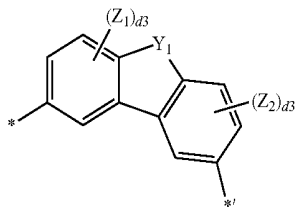
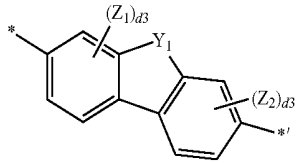
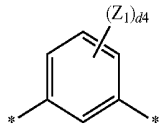
2. The condensed cyclic compound as claimed in claim 1, wherein

L₁ to L₃ are each independently a group represented by one of the following Formulae 3-1 to 3-49:

Formula 3-1



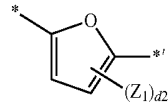
147
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148
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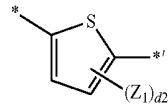
Formula 3-2

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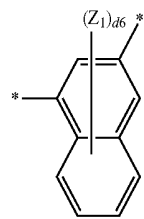
Formula 3-3

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Formula 3-4

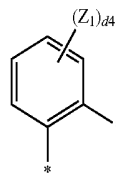
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Formula 3-5

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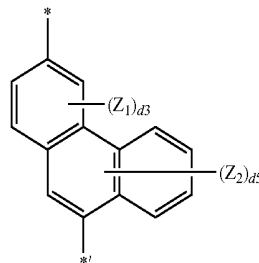


Formula 3-6

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Formula 3-7

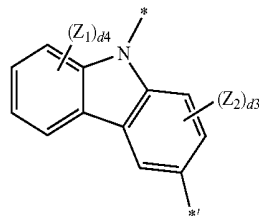
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Formula 3-8

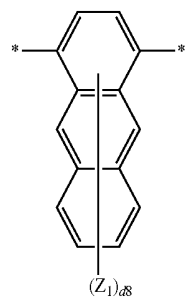
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Formula 3-9

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Formula 3-10

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Formula 3-11

Formula 3-12

Formula 3-13

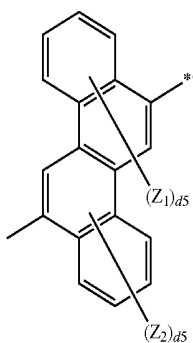
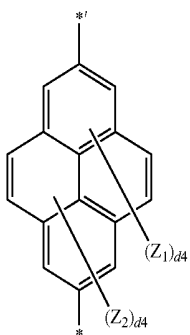
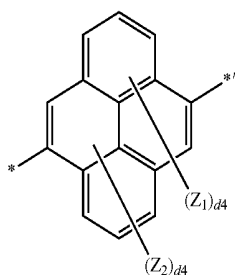
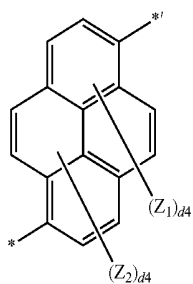
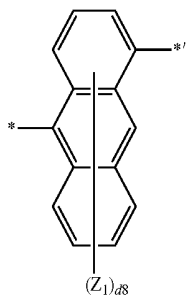
Formula 3-14

Formula 3-15

Formula 3-16

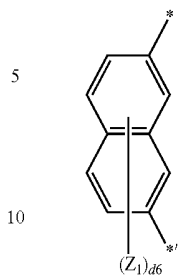
Formula 3-17

149
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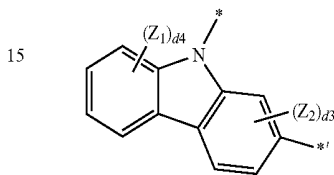


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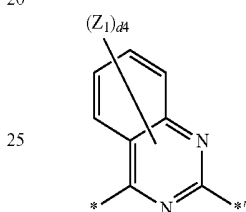
Formula 3-18



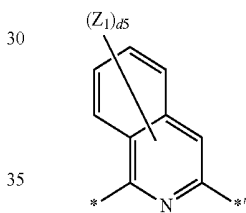
Formula 3-19



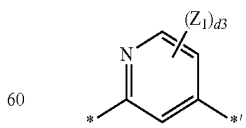
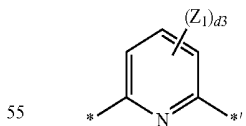
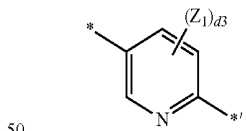
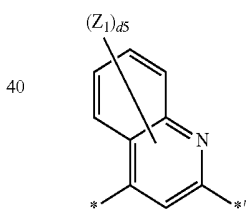
Formula 3-20



Formula 3-21



Formula 3-22



Formula 3-23

Formula 3-24

Formula 3-25

Formula 3-26

Formula 3-27

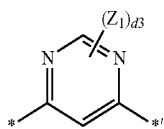
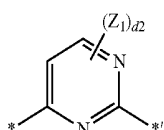
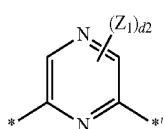
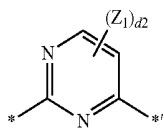
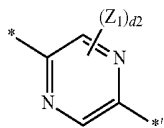
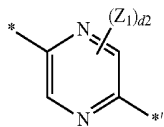
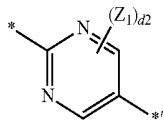
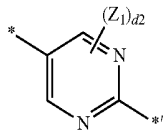
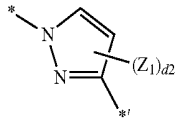
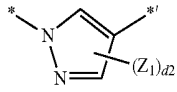
Formula 3-28

Formula 3-29

Formula 3-30

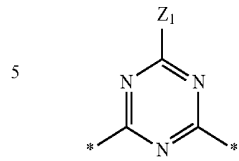
Formula 3-31

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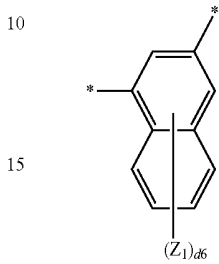


152
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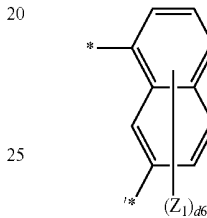
Formula 3-32



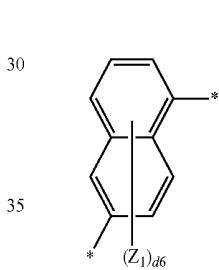
Formula 3-33



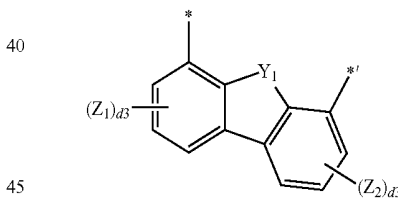
Formula 3-34



Formula 3-35

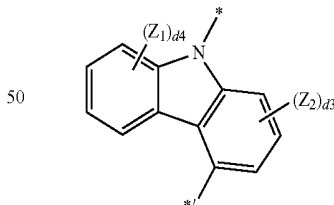


Formula 3-36



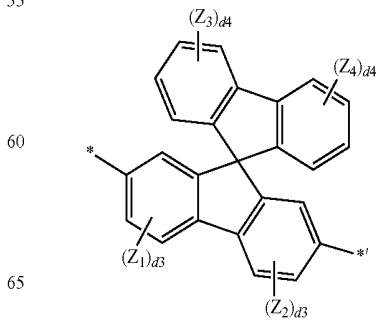
Formula 3-37

Formula 3-38



Formula 3-39

Formula 3-40



Formula 3-41

Formula 3-42

Formula 3-43

Formula 3-44

Formula 3-45

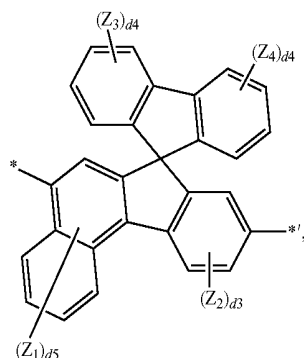
Formula 3-46

Formula 3-47

Formula 3-48

153

-continued



wherein, in Formulae 3-1 to 3-49,

Y_1 is O, S, C(Z_5)(Z_6), N(Z_5), or Si(Z_5)(Z_6),

Z_1 to Z_6 are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkenyl group, a C_1 - C_{20} alkynyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a triazinyl group, —Si(Q_{31})(Q_{32})(Q_{33}), —B(Q_{31})(Q_{32}), —C(=O)(Q_{31}), —S(=O)₂(Q_{31}), and —P(=O)(Q_{31})(Q_{32}),

wherein Q_{31} to Q_{33} are each independently selected from a C_1 - C_{10} alkyl group, a C_1 - C_{10} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group,

d_2 is 1 or 2,

d_3 is an integer of 1 to 3,

d_4 is an integer of 1 to 4,

d_5 is an integer of 1 to 5,

d_6 is an integer of 1 to 6,

d_8 is an integer of 1 to 8, and

* and *' each indicate a binding site to a neighboring atom.

3. The condensed cyclic compound as claimed in claim 1, wherein

L_1 to L_3 are each independently selected from:

a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, a spiro-benzofluorene-fluorene group, a benzofluorene group, a dibenzofluorene group, a phenanthrene group, an anthracene group, a dibenzofuran group, a dibenzothiophene group, a dibenzosilole group, and a carbazole group; and

a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, a spiro-benzofluorene-fluorene group, a benzofluorene group, a dibenzofluorene group, a phenanthrene group, an anthracene group, a dibenzofuran group, a dibenzothiophene group, a dibenzosilole group, and a carbazole group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a

Formula 3-49

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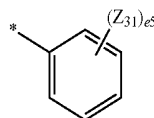
biphenyl group, a terphenyl group, a naphthyl group, —Si(Q_{31})(Q_{32})(Q_{33}), and —B(Q_{31})(Q_{32}), and Q_{31} to Q_{33} are each independently selected from a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, and a pyridinyl group.

4. The condensed cyclic compound as claimed in claim 1, wherein a_1 to a_3 are each independently 0 or 1.

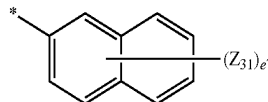
5. The condensed cyclic compound as claimed in claim 1, wherein

Ar_1 and Ar_2 are each independently a group represented by one of the following Formulae 5-1 to 5-30:

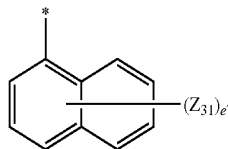
Formula 5-1



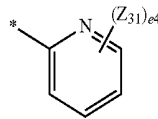
Formula 5-2



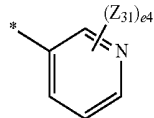
Formula 5-3



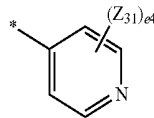
Formula 5-4



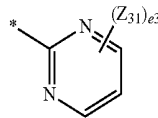
Formula 5-5



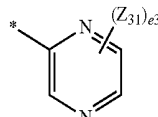
Formula 5-6



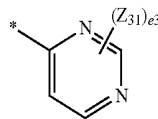
Formula 5-7



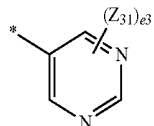
Formula 5-8



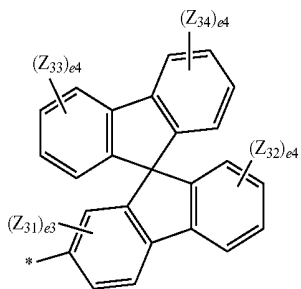
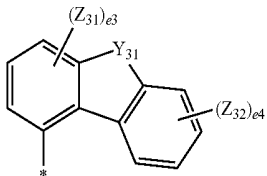
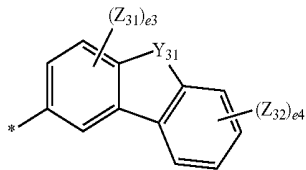
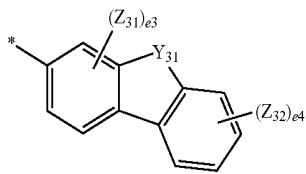
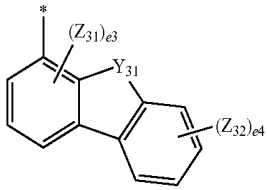
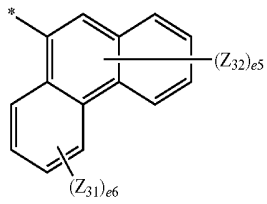
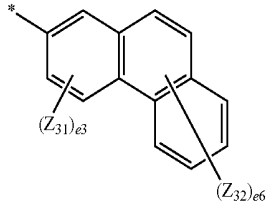
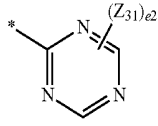
Formula 5-9



Formula 5-10



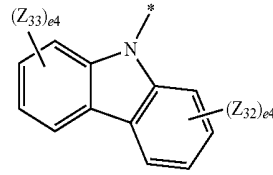
155
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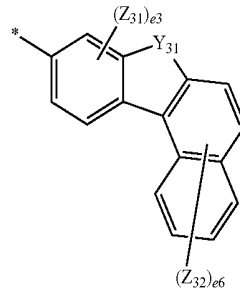
Formula 5-11

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Formula 5-12

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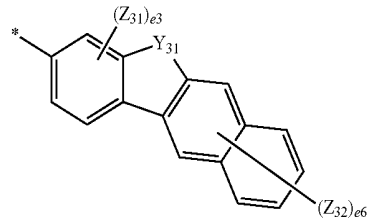


Formula 5-13

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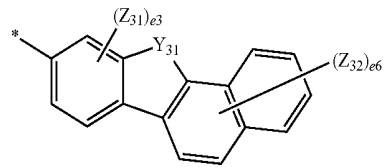
Formula 5-14

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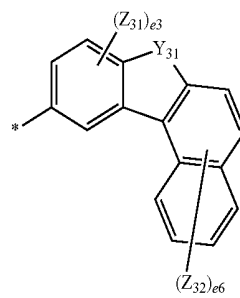
Formula 5-15

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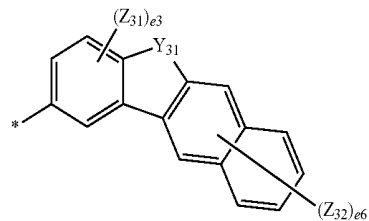
Formula 5-16

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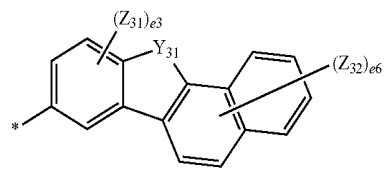
Formula 5-17

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Formula 5-18

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Formula 5-19

Formula 5-20

Formula 5-21

Formula 5-22

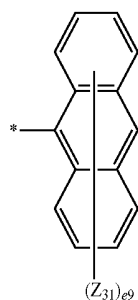
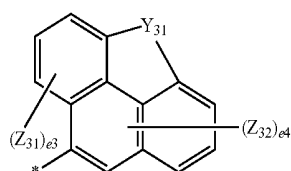
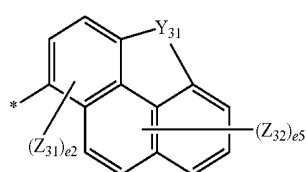
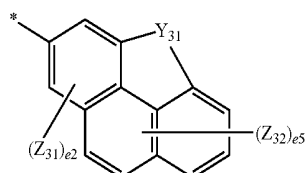
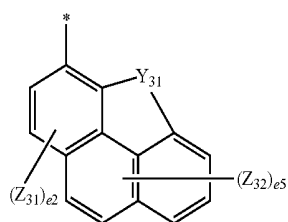
Formula 5-23

Formula 5-24

Formula 5-25

157

-continued



wherein, in Formulae 5-1 to 5-30,

Y_{31} is O, S, C(Z_{35})(Z_{36}), N(Z_{35}), or Si(Z_{35})(Z_{36}),

Z_{31} to Z_{36} are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkenyl group, a C_1 - C_{20} alkynyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a triazinyl group, —Si(Q_{31})(Q_{32})(Q_{33}), —B(Q_{31})(Q_{32}), —C(=O)(Q_{31}), —S(=O)₂(Q_{31}), and —P(=O)(Q_{31})(Q_{32}),

wherein Q_{31} to Q_{33} are each independently selected from a C_1 - C_{10} alkyl group, a C_1 - C_{10} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group,

158

Formula 5-26

e2 is 1 or 2,

e3 is an integer of 1 to 3,

e4 is an integer of 1 to 4,

e5 is an integer of 1 to 5,

5 e6 is an integer of 1 to 6,

e7 is an integer of 1 to 7,

e9 is an integer of 1 to 9, and

* and *' each indicate a binding site to a neighboring atom.

Formula 5-27

6. The condensed cyclic compound as claimed in claim 1, wherein

Ar_1 and Ar_2 are each independently selected from:

a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a carbazolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzonaphthofuranyl group, a dinaphthofuranyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a benzonaphthosilolyl group, and a dinaphthosilolyl group; and

Formula 5-28

a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a carbazolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzonaphthofuranyl group, a dinaphthofuranyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a benzonaphthosilolyl group, and a dinaphthosilolyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, and —Si(Q_{31})(Q_{32})(Q_{33}), and

Formula 5-29

Q_{31} to Q_{33} are each independently selected from a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

Formula 5-30

7. The condensed cyclic compound as claimed in claim 1, wherein b1 and b2 are each 1.

8. The condensed cyclic compound as claimed in claim 1, wherein

R_1 to R_{20} are each independently selected from:

a group represented by Formula 2;

hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a C_1 - C_{20} alkyl group, and a C_1 - C_{20} alkoxy group;

a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacacenyl group, a pentacacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a thiophenyl group, a furanyl group, a carbazolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a

159

dibenzothiophenyl group, a benzonaphthofuranyl group, a dinaphthofuranyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a benzonaphthosilolyl group, a dinaphthosilolyl group, a benzimidazolyl group, a benzoimidazonaphthoimidazolyl group, and an imidazopyridinyl group;

a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a thiophenyl group, a furanyl group, a carbazolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzonaphthofuranyl group, a dinaphthofuranyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a benzonaphthosilolyl group, a dinaphthosilolyl group, a benzimidazolyl group, a benzoimidazonaphthoimidazolyl group, and an imidazopyridinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, and —Si(Q₃₁)(Q₃₂)(Q₃₃); and

—Si(Q₁)(Q₂)(Q₃), B(Q₁)(Q₂), —C(=O)(Q₁), —S(=O)₂(Q₁), and —P(=O)(Q₁)(Q₂),

wherein Q₁ to Q₃ and Q₃₁ to Q₃₃ are each independently selected from a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

9. The condensed cyclic compound as claimed in claim 1, wherein

L₁ to L₃ are each independently selected from:

a benzene group; and

a benzene group, substituted with deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group,

a₁ to a₃ are each independently 0 or 1,

Ar₁ and Ar₂ are each independently selected from:

a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a dibenzofuranyl group, and a dibenzothiophenyl group; and

a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀

160

alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, and —Si(Q₃₁)(Q₃₂)(Q₃₃);

b₁ and b₂ are each 1, and

R₁ to R₂₀ are each independently selected from:

a group represented by Formula 2;

hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a C₁-C₂₀ alkyl group, and a C₁-C₂₀ alkoxy group;

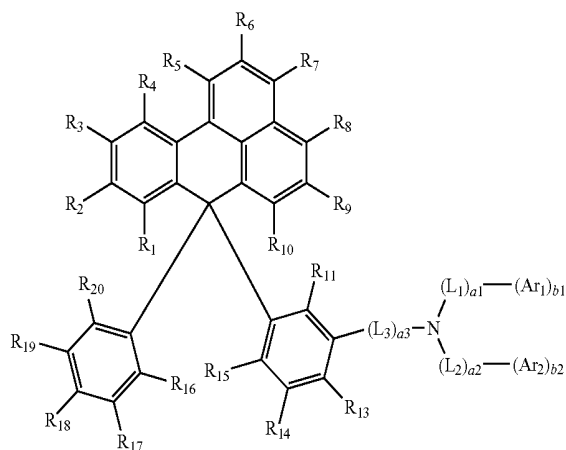
a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group;

a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, and —Si(Q₃₁)(Q₃₂)(Q₃₃); and —Si(Q₁)(Q₂)(Q₃), B(Q₁)(Q₂), —C(=O)(Q₁), —S(=O)₂(Q₁), and —P(=O)(Q₁)(Q₂),

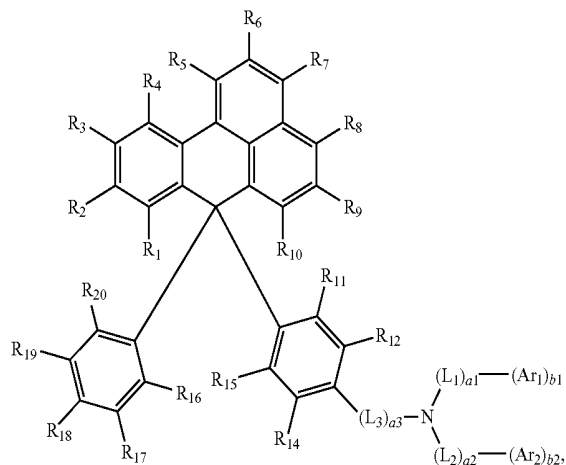
wherein Q₁ to Q₃ and Q₃₁ to Q₃₃ are each independently selected from a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

10. The condensed cyclic compound of claim 1, wherein the condensed cyclic compound represented by Formula 1 is represented by Formula 1A or 1B:

<Formula 1A>



<Formula 1B>



wherein, in Formulae 1A and 1B,

L_1 to L_3 , a_1 to a_3 , Ar_1 , Ar_2 , b_1 , b_2 , and R_1 to R_{20} are defined the same as L_1 to L_3 , a_1 to a_3 , Ar_1 , Ar_2 , b_1 , b_2 , and R_1 to R_{20} of Formula 1.

11. The condensed cyclic compound of claim 10, wherein, in Formulae 1A and 1B,

L_1 to L_3 are each independently selected from:

a benzene group; and

a benzene group, substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group,

a_1 to a_3 are each independently 0 or 1,

Ar_1 and Ar_2 are each independently selected from:

a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a dibenzofuranyl group, and a dibenzothiophenyl group; and

a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, and —Si(Q_{31})(Q_{32})(Q_{33}), b_1 and b_2 are each 1, and

R_1 to R_{20} are each independently selected from:

hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a C_1 - C_{20} alkyl group, and a C_1 - C_{20} alkoxy group;

a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group;

a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, and —Si(Q_{31})(Q_{32})(Q_{33}); and

—Si(Q_1)(Q_2)(Q_3), B(Q_1)(Q_2), —C(=O)(Q_1), —S(=O)₂(Q_1), and —P(=O)(Q_1)(Q_2),

wherein Q_1 to Q_3 and Q_{31} to Q_{33} are each independently selected from a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

12. An organic light-emitting device, comprising:

a first electrode;

a second electrode facing the first electrode; and

an organic layer between the first electrode and the second electrode, the organic layer including an emission layer, wherein the organic layer includes the condensed cyclic compound as claimed in claim 1.

13. The organic light-emitting device as claimed in claim 12, wherein

the first electrode is an anode,

the second electrode is a cathode,

the organic layer further includes a hole transport region between the first electrode and the emission layer and an electron transport region between the emission layer and the second electrode,

the hole transport region includes a hole injection layer, a hole transport layer, an emission auxiliary layer, an electron blocking layer, or any combination thereof, and

the electron transport region includes a buffer layer, a hole blocking layer, an electron control layer, an electron transport layer, an electron injection layer, or any combination thereof.

14. The organic light-emitting device as claimed in claim 13, wherein the hole transport region includes the condensed cyclic compound.

15. The organic light-emitting device as claimed in claim 13, wherein:

the hole transport region includes a hole transport layer, and

the hole transport layer includes the condensed cyclic compound.

16. The organic light-emitting device as claimed in claim 13, wherein:

the hole transport region includes a p-dopant, and

a lowest unoccupied molecular orbital (LUMO) of the p-dopant is —3.5 eV or less.

17. The organic light-emitting device as claimed in claim 16, wherein the p-dopant includes a quinone derivative, a metal oxide, a cyano group-containing compound, or any combination thereof.

18. The organic light-emitting device as claimed in claim 13, wherein the electron transport region includes an alkali metal, an alkaline earth metal, a rare-earth metal, an alkali metal compound, an alkaline earth-metal compound, a rare-earth metal compound, an alkali metal complex, an alkaline earth-metal complex, a rare-earth metal complex, or any combination thereof.

19. The organic light-emitting device as claimed in claim 12, wherein:

the emission layer includes a dopant and a host, and

the host includes at least one selected from an anthracene-based compound, a pyrene-based compound, and a spiro-bifluorene-based compound.

20. The organic light-emitting device as claimed in claim 12, wherein:

the emission layer is a first color light-emitting layer,

the organic light-emitting device further includes i) at least one second color light-emitting layer or ii) at least one second color light-emitting layer and at least one third color light-emitting layer, between the first electrode and the second electrode,

a maximum emission wavelength of the first color light-emitting layer, a maximum emission wavelength of the second color light-emitting layer, and a maximum emission wavelength of the third color light-emitting layer are identical to or different from each other, and first color light and second color light are emitted in the form of mixed light, or the first color light, the second color light, and third color light are emitted in the form of mixed light.

* * * * *

专利名称(译)	缩合环状化合物和包括其的有机发光器件		
公开(公告)号	US10411191	公开(公告)日	2019-09-10
申请号	US15/665703	申请日	2017-08-01
[标]申请(专利权)人(译)	三星显示有限公司		
申请(专利权)人(译)	三星DISPLAY CO. , LTD.		
当前申请(专利权)人(译)	三星DISPLAY CO. , LTD.		
[标]发明人	ITOI HIROAKI		
发明人	ITOI, HIROAKI		
IPC分类号	H01L51/00 C07D307/77 C07D251/12 C07D239/24 C07D209/90 C09B57/00 C09K11/06 H01L51/50 C07D333/76 C07C211/54 C07C211/58 C09B69/00 C07D307/91 C07C211/61		
CPC分类号	H01L51/0056 C07C211/58 C07C211/61 C07D209/90 C07D239/24 C07D251/12 C07D307/77 C07D307/91 C07D333/76 C09B57/00 C09B57/008 C09B69/008 C09K11/06 H01L51/006 H01L51/0054 H01L51/0058 H01L51/0059 H01L51/504 H01L51/5072 C07C211/54 H01L51/5056 C07C2603/97 C07C2603/18 C07C2603/42 C07D409/12 H01L51/0052 H01L51/0061 H01L51/0073 H01L51/0074 H01L51/50 H01L51/5048		
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摘要(译)

缩合环状化合物和包含其的有机发光装置，该稠合环状化合物由式1表示：

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190
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110